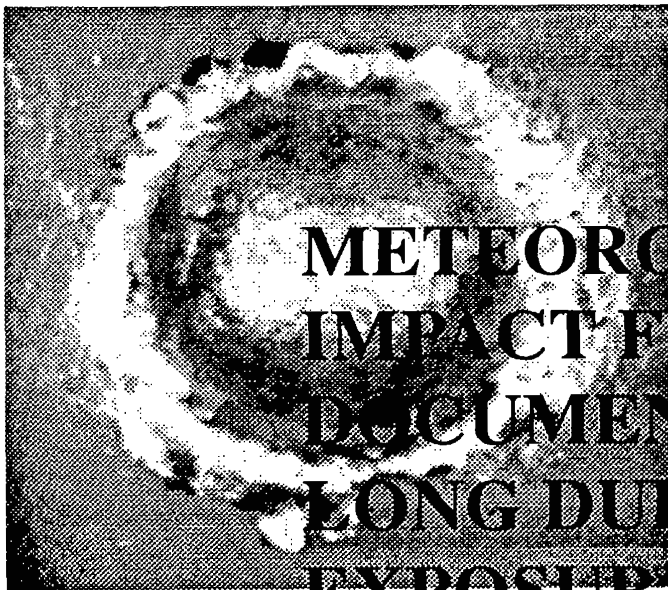

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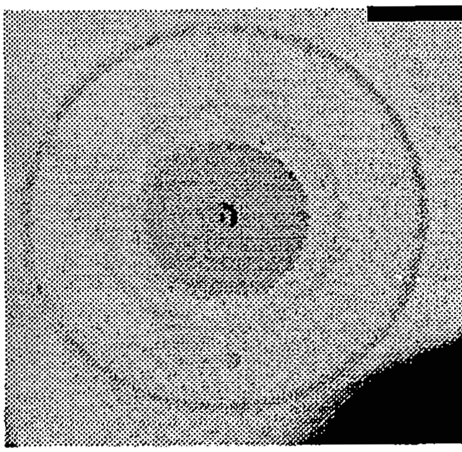
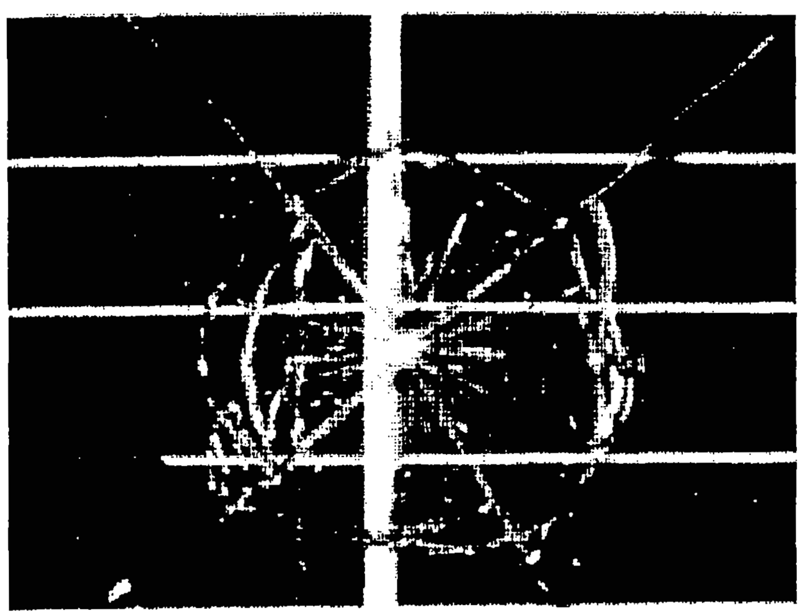


A Preliminary Report

Compiled by Members of the LDEF Meteoroid and Debris Special Investigation Group

August 1990



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METEOROID AND DEBRIS IMPACT FEATURES DOCUMENTED ON THE LONG DURATION EXPOSURE FACILITY: A PRELIMINARY REPORT

COMPILED BY MEMBERS OF THE LDEF

METEOROID AND DEBRIS SPECIAL INVESTIGATION GROUP

AUGUST 1990

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All of this work, and the LDEF itself, would not have become a reality without the continuing, career-long support of LDEF Project Scientist Bill Kinard. Finally, we thank our families whose support, during our long absences, made this work and report possible.

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SECTION 1

INTRODUCTION

1. INTRODUCTION

The Long Duration Exposure Facility (LDEF) was host to several individual experiments designed to characterize aspects of the meteoroid and space-debris environment in low-Earth orbit. It was realized from the very start, however, that the most complete way to accomplish this goal was to exploit the meteoroid and debris record of the entire LDEF. The Meteoroid and Debris Special Investigation Group (M&D SIG) was organized to achieve this end.

Two dominant goals of the M&D SIG are the documentation of the impact record of the entire LDEF, and the dissemination of this information to all interested workers. As a major step towards the accomplishment of these goals, we have prepared this publication describing the M&D SIG observations of impact feature made during LDEF deintegration activities at Kennedy Space Center (KSC) in the spring of 1990. It is hoped that this report will serve as a useful guide for spacecraft designers as well as for meteoroid and space-debris workers, and that it will spur further work on the LDEF impact-laden surfaces collected by the M&D SIG and now available for allocation to qualified investigators.

An important aim in the writing of this report has been to present all data and descriptions of impact features in a form which, though terse, remains comprehensible to the wider community. There is a deliberate minimum of interpretation. Thus, this catalog is intended to serve as a guide to the impact features found on LDEF and is not intended to stand as a definitive interpretive work.

M&D SIG members at KSC gathered a specific set of data for all large impacts present on LDEF, which included (1) the size, type, location, and feature characteristics of all impacts deserving of documentation ($\geq$0.5 mm in diameter for thick surfaces, $\geq$0.3 mm in diameter for thinner blanket-type materials, and others exhibiting unusual characteristics), (2) digitized, stereo imaging in color of all large impact features, and (3) the numbers of all impact features large enough to be observed visually, but too small to warrant detailed documentation. In addition, we collected any other information on these impact features which could be gathered visually was recorded. All of these data and images are securely stored in the Johnson Space Center (JSC) Curatorial Facility Data Vault. These images are now in the process of being reduced to yield accurate impact crater diameter and depth data. Since this data reduction was not complete at the time of this writing, however, please note that the crater diameters given in this catalog come from measurements made with a scale on a video screen, with typical error of perhaps 10%. All data from reduced images will be published in a later compilation.

The M&D SIG has endeavored to arrange all M&D data collected at KSC into an easily accessible, readily understandable form, first describing the procedures employed in surveying and documenting impact features. The results are represented by detailed tray summaries, which are ordered by experiment "Bay" and "Row" location, followed by descriptions of the impact features found on thermal panels, scuff plates, the walking beam, and the aluminum frame of the LDEF itself. Please note that the descriptions of bolts, clamps, shims, and reflectors are included with their respective experiment trays or thermal panels, and are not separated into independent sections. The curatorial techniques employed for LDEF samples, are described next, followed by the current status of curated M&D SIG samples and equipment.

Finally, a series of recommendations are presented which, if implemented, would provide the necessary scientific and engineering data with which to design and operate spacecraft safely in low-Earth orbit, while simultaneously yielding an unparalleled view of the meteoroid and debris complex.

SECTION 2

DATA-ACQUISTION PROCEDURES

2.A. GENERAL

This section describes the various procedures and equipment used by the Meteoroid & Debris Special Investigation Group (M&D SIG) during deintegration operations of the Long Duration Exposure Facility (LDEF) at the Kennedy Space Center, and provides the background necessary for understanding the data presented in Section 3.

Section 2.B. presents a description of the various impact-feature morphologies encountered by the M&D SIG Analysis Team (A-Team) during their examination of the entire LDEF spacecraft. Many of the terms and characteristics described within this section are used repeatedly in the individual tray summaries in Section 3.

In order to efficiently complete the M&D SIG deintegration operations with a minimum of missed or lost data, special procedures and equipment were complied at the Johnson Space Center prior to the retrieval of the LDEF spacecraft. Sections 2.C through 2.F explain the data-collection procedures and the equipment utilized by the M&D SIG A-Team during LDEF deintegration.

Section 2.C details the procedures used during the nine primary M&D SIG A-Team surveys of LDEF. This section also describes both the origin ([0,0] reference point) used on the various LDEF surfaces and the Coordinate Registration System used for measuring the X- and Y-coordinates of impact features on those surfaces.

Section 2.D. specifies the procedures by which the impact features were documented photographically during the M&D SIG deintegration operations. The Stereo-Microscope Imaging System, which was used for most photodocumentation, is described in detail, as are associated software operations.

Since the M&D SIG was responsible for trisecting, packaging, and shipping of the 17 Scheldal G411500 thermal blankets flown on LDEF, special procedures and shipping containers were developed to ensure the safety of the thermal blankets during shipping, storage, and preliminary viewing or analysis. Section 2.E. explains procedures followed in processing the thermal blankets and describes the specially-designed thermal-blanket boxes.

By reading all of Section 2, the reader should gain a broad familiarity with the M&D SIG LDEF deintegration procedures and equipment, which will assist the reader in understanding the data presented within the Section 3 summary reports.

2.B IMPACT FEATURE MORPHOLOGY AND DIAMETER MEASUREMENTS

During approximately a three month period (February through April, 1990), members of the M&D SIG, as well as several other individuals, examined and photodocumented thousands of impact-related features from all exposed surfaces of the LDEF spacecraft. Approximately 25 percent of the exposed experimental surface area which flew on LDEF was dedicated to the study of micrometeoroids and debris. However, as a result of LDEF extended stay in orbit, it was decided to examine the entire spacecraft for large (≥0.5 mm in diameter) impact features in order to gain a better statistical understanding of the micrometeoroid and debris fluxes for these size particles. Thus, one goal of the M&D SIG A-Team was to examine and photodocument all features ≥0.5 mm in diameter so that such information could be added to the overall particle size database expected from the dedicated meteoroid and debris experiments. Furthermore, it was decided early during the M&D SIG operations at the Kennedy Space Center (KSC) to lower the minimum threshold diameter for pnetrations to ≥0.3 mm in diameter. The primary reasons for making diameter measurements during the KSC documentation operations were to (1) determine if the minimum feature-size criterion had been met and (2) develop a first-order database for feature sizes and locations which would supplement the detailed analytical database to be developed by the M&D SIG from the stereo-video image pairs of impact features recorded at KSC. During the M&D SIG operations at KSC, feature diameters were estimated to two decimal places (*e.g.*, 0.51 mm) using the conversion graphs discussed below. However, there were several sources of error in these

measurements, as described later, and a decision was made to report the diameters to the nearest 0.1 mm within this publication. This represents the level of accuracy which could realistically be expected from the measurement techniques and the large number of system operators employed by the M&D SIG. The image files are currently being reduced to yield more accurate data (*e.g.*, depth, diameter).

This section describes the general morphology of impacted-related features encountered during the examination and photodocumentation of the diverse materials flown on LDEF. The methods, and their limitations, used to determine the *estimated* feature diameters on the various classes of materials are presented as well. For addtional information on impact feature morpholgy, and the impact process itself, interested readers are directed to References 1 and 2.

2.B.1 DIAMETER MEASUREMENTS

All LDEF surfaces were scanned for impact craters with center-of-rim to center-of-rim diameters ≥0.5 mm, and for impact penetration holes with center-of-rim to center-of-rim diameters ≥0.3 mm (Figure 1). Features which met the minimum size requirements were imaged, as were smaller features which exhibited some unusual or interesting characteristics (*e.g.*, the presence of associated debris, secondaries, the scarcity of features on a particular surface under examination). After visually identifying and recording the coordinates of all impact features on a surface which were potentially large enough for digital imaging (see Section 2.C.6.d), the Stereo-Microscope Imaging System (SMIS) was used to examine each registered feature in detail. During this examination, the feature's estimated diameter was determined by placing a metric scale over the feature's image on a video-display screen. The measured screen diameter would then be converted to the estimated feature diameter by locating the screen-measured diameter on a straight-line correlation graph and reading the corresponding feature diameter (see Section 2.D.4.1 and Figure 31 for details on this process and the generation of the conversion charts). Two such graphs, each containing the four commonly used magnifications (6X, 12X, 25X, and 50X), were part of each SMIS and were used by all operators. When non-standard magnifications were used, an appropriate correction factor was applied to determine the estimated feature diameter from the existing graphs.

The majority of impact features examined at KSC possessed raised rims, some of which were irregular in shape resembling a flower "petal". In practice, the microscope was focused on the top of the feature's rim, and the center of the ridge which was in focus was used to make the estimated diameter measurements (Figures 1 and 2). When highly asymmetric rim shapes were present, this approach lead to three types of measurement errors: (1) inaccurate diameter measurements, (2) reporting of symmetrical craters as elliptical, and (3) reporting of elliptical craters as symmetrical (Figure 3). Since crater diameters are reported here only to the nearest 0.1 mm, the effect on the database of the inaccuracies generated by the few cases of highly asymmetric rim shapes is minimal, and the number of reported elliptical features in this first-order database is

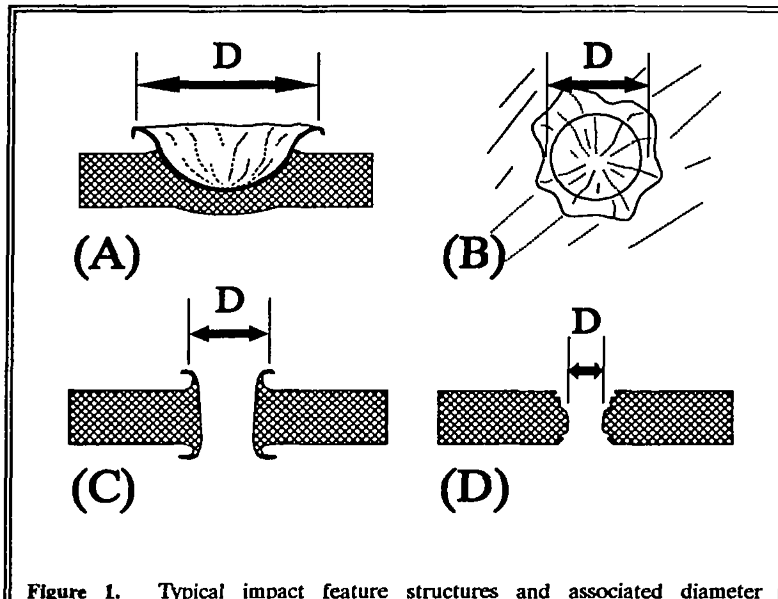


Figure 1. Typical impact feature structures and associated diameter measurements. (A) Cross-sectional view of feature with symmetrical rim and overturned lips, (B) Top view of [A], (C) Cross-sectional view of a penetration feature with symmetrical rim and overturned lips, (D) Cross-sectional view of a penetration feature without a rim.

Figure 2. Photograph of a symmetrically-shaped crater in an aluminum surface. Most features on LDEF were of this type. Small divisions on scale are in millimeters.

of limited use. Certainly all highly elliptical features were unambiguously identified, but identification of features with eccentricities on the order of 10 to 15% was subject to large uncertainties.

Penetration-hole diameters were measured from edge to edge when rims were not present as illustrated in Figure 1d. When rims were present and symmetrical, the distance between the centers of opposing rims was taken as the feature's diameter (Figure 1c). When rims were asymmetric, either as the result of an oblique impact, or more commonly, the result of the collapse of "molten" material, a case by case determination of the apparent hole diameter was made. This was done by examining the feature under the SMIS and determining the position of the hole edge beneath the collapsed rim (Figure 4). Since this situation usually occurred on thin polymeric surfaces, such as the Teflon thermal blankets of the A0178 experiment, the collapsed rim was somewhat translucent and an adequate view of the inside hole edges could be obtained.

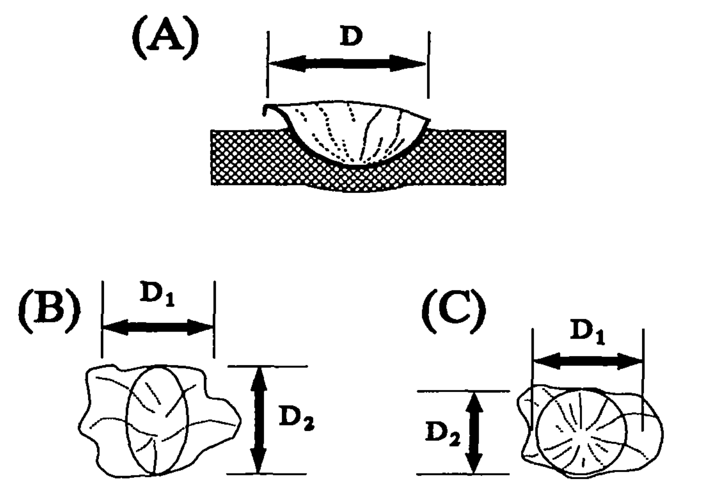


Figure 3. Three type of measurement errors that could result when measuring asymmetrical features. (A) Inaccurate diameter measurement due to missing rim, (B) an elliptical feature reported as symmetrical, and (C) a symmetrical feature reported as elliptical.

Elliptical features which had major- and minor axes which varied by ≥10%, and highly-oblique features (comet-shaped features whose lengths were several times greater than their maximum widths; Figures 5 and 6) are reported with the length of both axes indicated (*e.g.*, ~0.7 x 0.9 mm and ~0.4 x 1.3 mm). The limitations of the diameter measurement procedure in determining if features were elliptical in each type of surface were discussed above. Asymmetric rim formation was the major factor complicating diameter measurements. Accurate measurement of oblique-feature dimensions was often complicated by the poorly defined boundaries of the impact-affected area. The comet-shaped features usually exhibited clearly defined "heads" and more diffuse, or less well defined "tails". These were often composed of a series of microcraters which diminished in size and number with distance from the head to tail center line. The dimensions for such features were measured between the furthest points of altered surface material discernable under optical magnification.

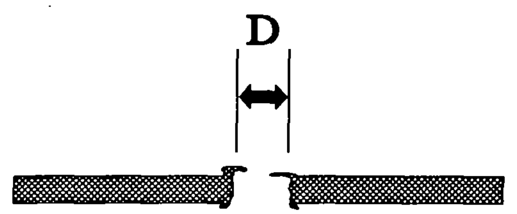


Figure 4. Example of the general morphology and the associated feature diameter of a penetration hole through a single-layer thermal blankets possessing a collapsed rim.

2.B.2 IMPACT FEATURE MORPHOLOGY

In the subsections which follow, the general morphological descriptions are presented, along with various diagrams and photographs, of impact features observed within the various categories of surface materials.

Figure 5. Photograph of an elongate feature in an aluminum surface, probably from an extremely low-angle (<5°) or oblique impact. View measures approximately 1.5 cm across.

These categories include (1) metals, (2) glasses and crystalline solids, (3) polymers (including the Scheldahl G411500 thermal blankets), (4) composites, and (5) multi-layered thermal blankets and other multi-layer structures. Unusual feature morphologies are described individually within the appropriate experiment-tray summary reports (Section 3.B).

The impact of a hypervelocity particle into most surfaces will cause the ejection of solid, liquid, and gaseous materials from the impact zone. The ejection of such materials often left visible deposits on many LDEF surfaces, and there were many instances where ejected materials could be seen (on the same or adjacent surfaces) partially or completely surrounding an impact site. When such debris deposits were encountered, the images acquired during the photodocumentation of such features usually included the associated debris deposits.

2.B.2.a Metals

Approximately 75 percent of the exposed surface area on LDEF consisted of coated and uncoated aluminum alloys. A large portion of this area consisted of anodized aluminum structural members which were held together with 303 stainless steel bolts. All of the exposed experiment-tray flanges, clamps (except for a few), and the structural members of the LDEF frame were constructed from chromic-anodized 6061-T6 aluminum. The same material was used in the fabrication of the space-end thermal panels, space- and Earth-end dummy plates, grapple-fixture tray surfaces (except for the actual grapple fixtures), experiment environment control cannisters (EECC), a variety of experiment-frame structures, and the experimental surfaces of the 25 whole or partial trays which made up the Space Debris Impact Experiment (S0001). The Earth-end thermal panels were anodized with a slightly different anodization process which resulted in their black color; the process itself is of a proprietary nature and cannot be detailed here. In addition, a variety of small uncoated metal samples were exposed as part of several experimental packages in order to evaluate the effects of the low-Earth orbital environment on their physical properties.

Coatings on metal surfaces ranged from the very thin single layers to the ~3 to 4 mils (~75 to 100 μm) thick Teflon/silver/adhesive coatings on aluminum components of several experimental surfaces (such as the Transverse Flat-Plate Heat Pipe Experiment [S1005] and the housing on the Thermal Control Surfaces Experiment [S0069]). Between these extremes there were many painted aluminum surfaces which had a variety of primer and top coats totaling ~1 to 2 mils (25 to 50 μm) in thickness. Many of these surfaces were painted white for thermal control.

The vast majority of impact craters identified in uncoated metal surfaces were symmetrical in shape and possessed a raised rim (Figures 1 and 2). A small percentage of these craters exhibited asymmetric rim shapes or petals, or were elliptical (Figures 5 and 6a). Several dozen highly elliptical features resulting from oblique, or grazing impacts (Figure 6b) were found on the Earth-end thermal panels. Such features were not uncommon on the various Earth-end thermal panels and, in general, possessed semi-minor axes of <0.5 mm, while the semi-major axes were commonly measured at >1.0 mm in length. These features were easily discernable on the black-anodized Earth-end thermal panels as the underlying aluminum substrate clearly stood out in areas of impact-induced damage. Several others were found in various locations around the spacecraft.

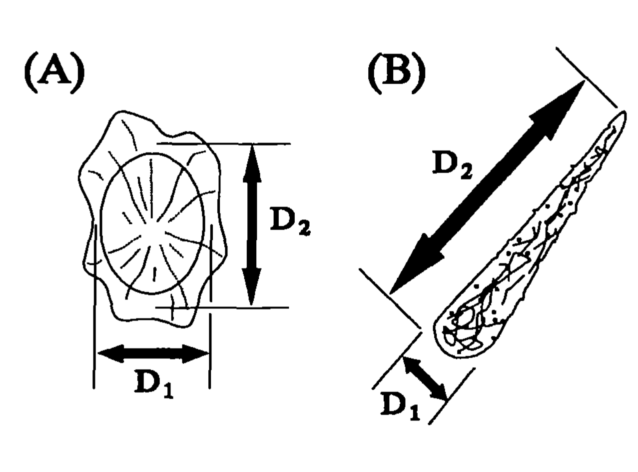


Figure 6. Elliptical and highly-oblique features and associated diameter measurements. (A) Top view of an elliptical feature with a symmetrical rim and (B) top view of a highly-oblique feature.

A few clearly identifiable multi-cratering events were found on metal surfaces. These unusual and rare impact features (Figure 7) consisted of tens to hundreds of smaller, well-formed craters lining the bottom, sides, and rims of the host crater formed by the overall impact. The diameter of the overall feature is reported in this paper, and comments describing the feature's morphology are included in the applicable summary reports.

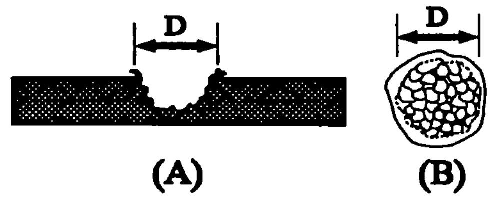


Figure 7. Illustration of the general morphology and the associated feature diameter of several apparent "multi-cratering" features documented on LDEF. (A) Cross-sectional view and (B) top view.

Impact penetrations through thin metal surfaces, such as the foils used in the Multiple-Foil Microabrasion Package Experiment (A0023), and a few large impacts through 0.0625" (1.6 mm) thick aluminum sheet metal had the general symmetrical hole and rim shapes depicted in Figure 1c. Very thin foils had correspondingly narrow rims which were not always evident under low magnification with the SMIS. However, hole-diameter measurements were easily made for these features regardless of the associated rim width.

Impacts >0.5 mm in diameter into painted metal surfaces generally produced associated spall zones in the paint which extended for several crater diameters around the standard-shaped crater in the underlying metal surface (Figures 8 and 9). On thin aluminum panels coated with several layers of paint there were frequently large, front-surface delamination zones extending tens of crater diameters around the impact sites. In these instances, the top layer of paint was apparently blown off of the surface by acoustic forces propagating through the thin panel. In many cases, diameters for these zones were measured and recorded in the comments field of the digitized image files.

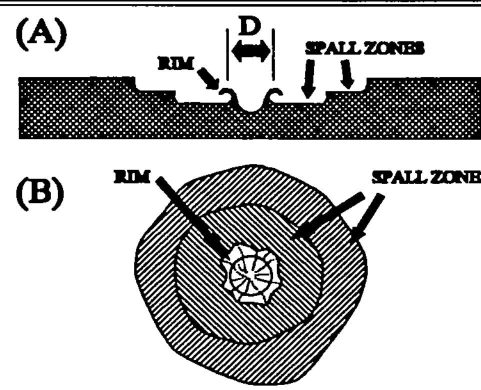


Figure 8. Illustration of the general morphology and associated feature diameter of impacts into painted metal surfaces. (A) Cross-sectional view and (B) top view.

Craters >0.5 mm in diameter on painted metal surfaces commonly possessed associated spall zones in the paint layers which extended for several crater diameters around the feature (Figures 8 and 9). On thin aluminum panels which were coated with several layers of paint there were frequently large, front-surface delamination zones extending tens of crater diameters around the impact sites. In many cases, diameters for these zones were measured and recorded in the comments field of the digitized image files.

The sizes of impact features in the few silvered-Teflon coated aluminum surfaces were evaluated differently than features found in other coated- and uncoated metal surfaces. Since the coating was relatively thick, 3 to 4 mils (75 to 100 μm), the impacts were treated as if they had occurred in the Teflon surface. Impacts into these types of surfaces produced holes in the Teflon, the general characteristics of which can be seen in Figures 1c and 4. These hole diameters were measured and are reported in the experiment-tray summaries. However, the mechanism of impact feature production on such surfaces was very different from the hole production (penetration) mechanism in true thin films; the laminated structure was never actually penetrated. Impacts into the bonded Teflon/aluminum surfaces produced a penetration/melt hole and a shock delamination zone in the Teflon. This delamination zone (*i.e.*, the debonding the polymer from the metal) commonly extended tens of hole diameters around the penetration. In most cases there was also a small crater in the aluminum surface beneath the Teflon coating, and there were commonly areas of discoloration (black) partially around some features. It should be noted

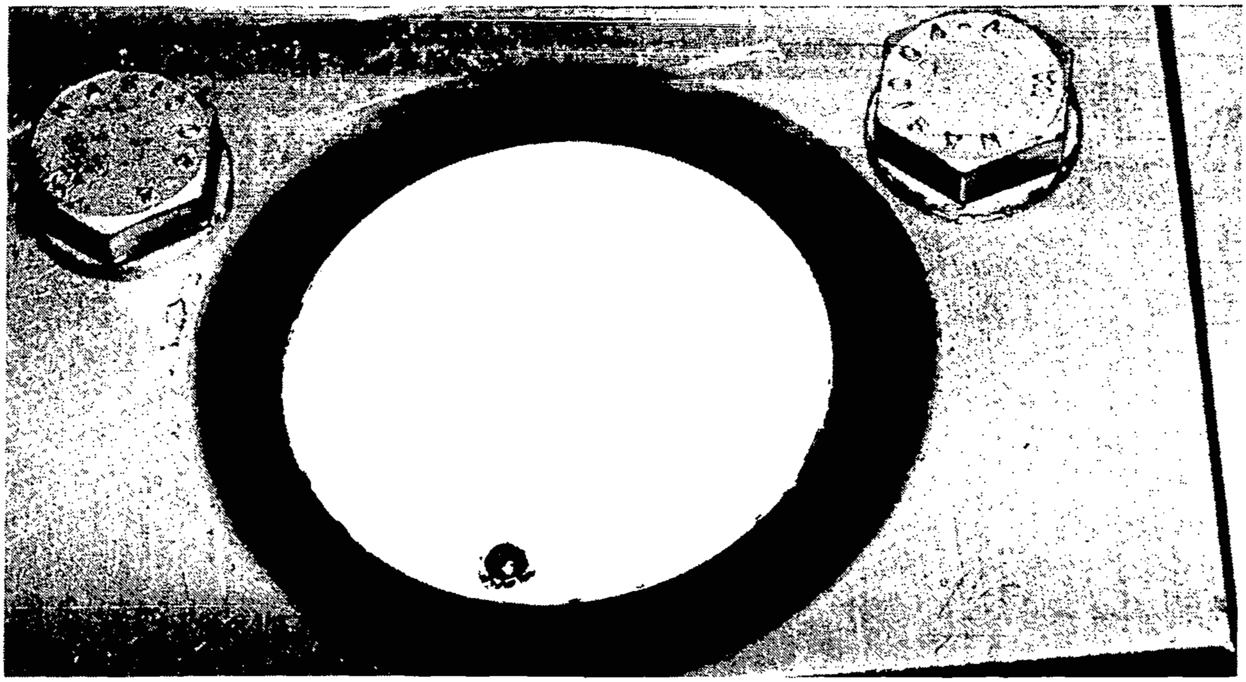


Figure 9. Impact into one of the paint specimens on an experiment-tray clamp. This particular feature was the largest impact feature found on the numerous tray clamps. View measures approximately ~6.5 cm across.

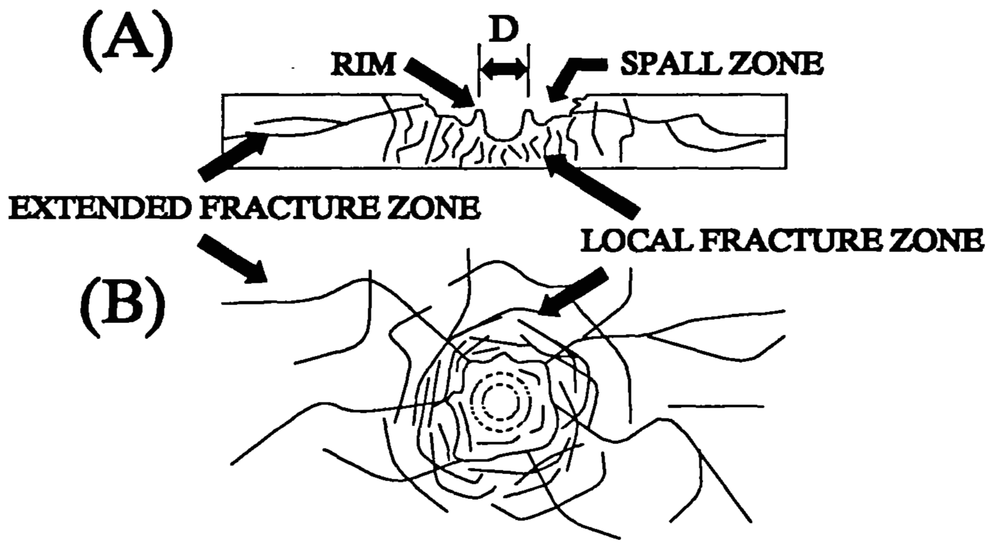


Figure 10. Illustration of the general morphology and associated feature diameter for features in glass or crystalline surfaces. (A) Cross-sectional view and (B) top view.

that the the impact feature sizes on such surfaces are not directly comparable to those on any other LDEF surfaces.

2.B.2.b Glasses and Crystalline Solids

Several square meters of surface area on LDEF were covered with glass encased solar cells, metal-oxide-silicon (MOS) capacitor-type detectors, germanium crystal wafers, and hundreds of small glass and crystalline samples. In addition, there were several experimental surfaces which utilized glass or crystalline materials as covers or windows. The morphology of impacts into and through glass and crystalline surfaces was dependent on the physical properties of the individual material. Such features had several, if not all, of the characteristics depicted in Figures 10 and 11 (*i.e.*, rims, spall zones, fracture zones, and extended fracture zones).

The extent of the spall and fracture zones, and the presence or absence of a rim around the central crater or penetration hole, were the major differences among impact features in glass and crystalline surfaces. When rims were present, or when there was a penetration hole without a rim, feature diameters were measured as depicted in Figures 1a and 1d, respectively. When rims were not present around a crater, the diameter of the residual crater was measured and reported (Figure 12).

Solar cell cover glasses exhibited more complex local fracture zones and fewer extended fractures zones, while smaller spall zones were found around impact sites in crystalline substrates. Occasionally, the fracture zones extended tens of crater diameters to the edges of the glass or crystalline substrate. Several quartz, Si, and Ge samples had impact-induced fractures which extended more than 2 cm. Crater/hole rims were often, but not always, missing in impact features in these materials. Spall zones were relatively large, which may account for the absence of rims. In such cases, primary spall-zone diameters were recorded when no part of the crater rim or residual crater was present.

2.B.2.c Polymers

Impact features into relatively thick polymeric materials, which were not exposed to extensive atomic oxygen erosion, had the same general morphology as impacts into uncoated metal surfaces. All diameter measurements were performed according to the procedures described above. The few impacts which were found in thick polymeric surfaces which were subjected to high atomic oxygen erosion (such as the reflectors on the leading-edge of thermal panels G21 and G23) looked worn and ill-defined. The diameters of these features were determined from the residual rims or craters.

Seventeen peripheral experiment trays were covered with Scheldahl G411500 thermal blankets (STB) consisting of an outer layer (space facing) of FEP Teflon (~120 μm thick) backed with a thin layer of vapor-deposited silver/inconel (~200 to 300 Å thick), which in turn was backed by DC1200 primer and Chemglaze Z306 black conductive paint (~80 to 100 μm thick). Impacts into these STBs produced holes similar to those pictured in Figures 1c, 4, 13, and 14. The major difference between these two types of features was the presence of a collapsed or an uncollapsed rim around the penetration hole.

Impacts into the STBs produced delamination zones which commonly extended tens of penetration-hole diameters, separating the Teflon layer from the silver/inconel and paint coatings. Penetration holes were often surrounded by one or more, whole or partial, colored rings which varied drastically in size and color. Diameter measurements were rarely recorded for these rings, but the rings were included in the field of view of the photodocumented features. In general, the ring structures were more pronounced around impact features on the leading-edge of LDEF STBs, as opposed to their trailing-edge counterparts. Although these ring structures were not associated with all penetration holes in the STBs, they were found in most cases. In the tray-summary reports, only penetration holes without rings are annotated, since the absence of rings was unusual.

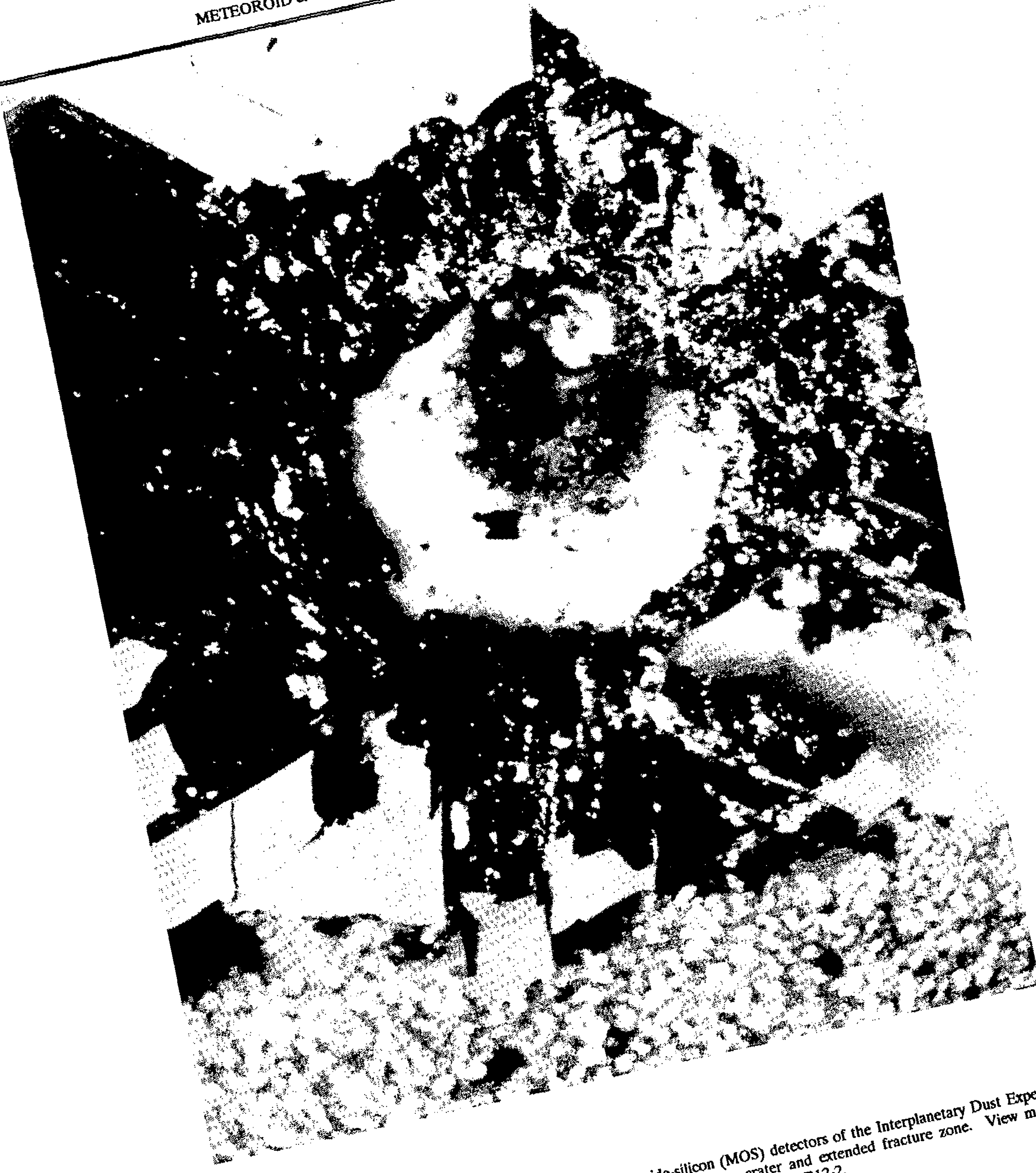


Figure 11. Photograph of an impact feature in one of the metal-oxide-silicon (MOS) detectors of the Interplanetary Dust Experiment (A0201; Bay B12). A central penetration hole (arrowed) is surrounded by a crater and extended fracture zone. View measures approximately 1 mm across. The same feature at a lower magnification can be seen in Figure B12-2.

Impacts into laminated polymeric films, such as the Kapton test specimens on experiment A0138, produced craters and penetration holes with the general structure described above, but also had areas of delamination which appeared as a bubble between layers. Reinforced layered plastics had less extensive delamination zones, and frayed fibers were often noted overlapping the holes in the polymer.

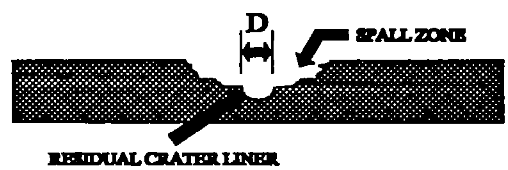


Figure 12. Illustration depicting the diameter that is reported for features where only a residual crater remains.

2.B.2.d Composite Structures

Several experiment trays on LDEF exposed various amounts of composite surfaces which were constructed from several layers of carbon, glass, and/or Kevlar woven fiber cloth laminated together with resin binders. Impact features in these materials were typically shaped like the rimless hole or crater pictured in Figure 15a. Impact-induced damage of these structures generally took the form of broken fibers with missing binder material from the affected volume. Remnant fibers often could be found extending over the area of missing or excavated binder material, complicating feature location and diameter measurements. In some cases the diameter of the affected volume increased with depth. This effect appeared to be a function of the composites' density, layering technique, layer spacing, and fiber type. Feature diameters were always measured at the surface, as depicted in Figure 15.

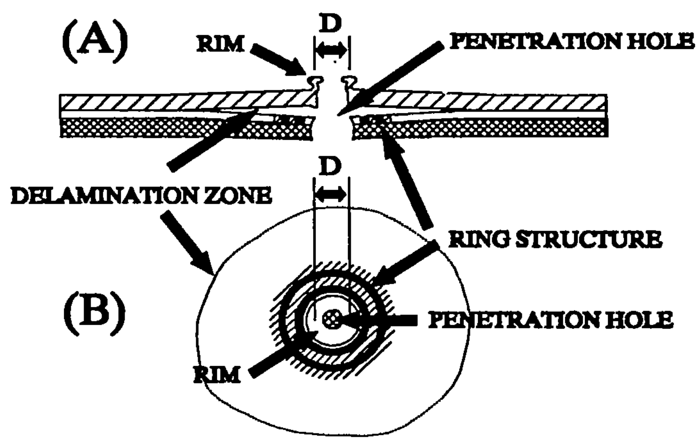


Figure 13. Illustration of the general structure and associated diameter measurement for features in the single-layered thermal blankets. (A) Cross-sectional view depicting the delamination of the Teflon layer from the underlying silver/inconel/paint surface and (B) top view showing the extent of the delamination zone and the presence of the "rings" generally found in association with these features.

Spall zones were commonly visible around impacts into the layered composite structures. The spall zones, which generally only extended a few crater diameters, represented areas where binder material had been ejected. Delamination-type zones were present around many large impacts in horizontally-lapped composite structures. These areas usually extended a few crater diameters beyond the spall zone, and were most easily identified in translucent materials. Images were extremely difficult to record on these types of surfaces due to the overlap of broken fibers and the generally dark color of such materials. An attempt was made to include all of the impact affected area in the acquired video images.

2.B.2.e Multi-layer Thermal Blankets and Structures

Several square meters on LDEF were covered with multi-layer thermal blankets (MTB) or other multi-layered surfaces. The majority of the MTBs were constructed from multiple layers of ~5 μm thick aluminized Mylar

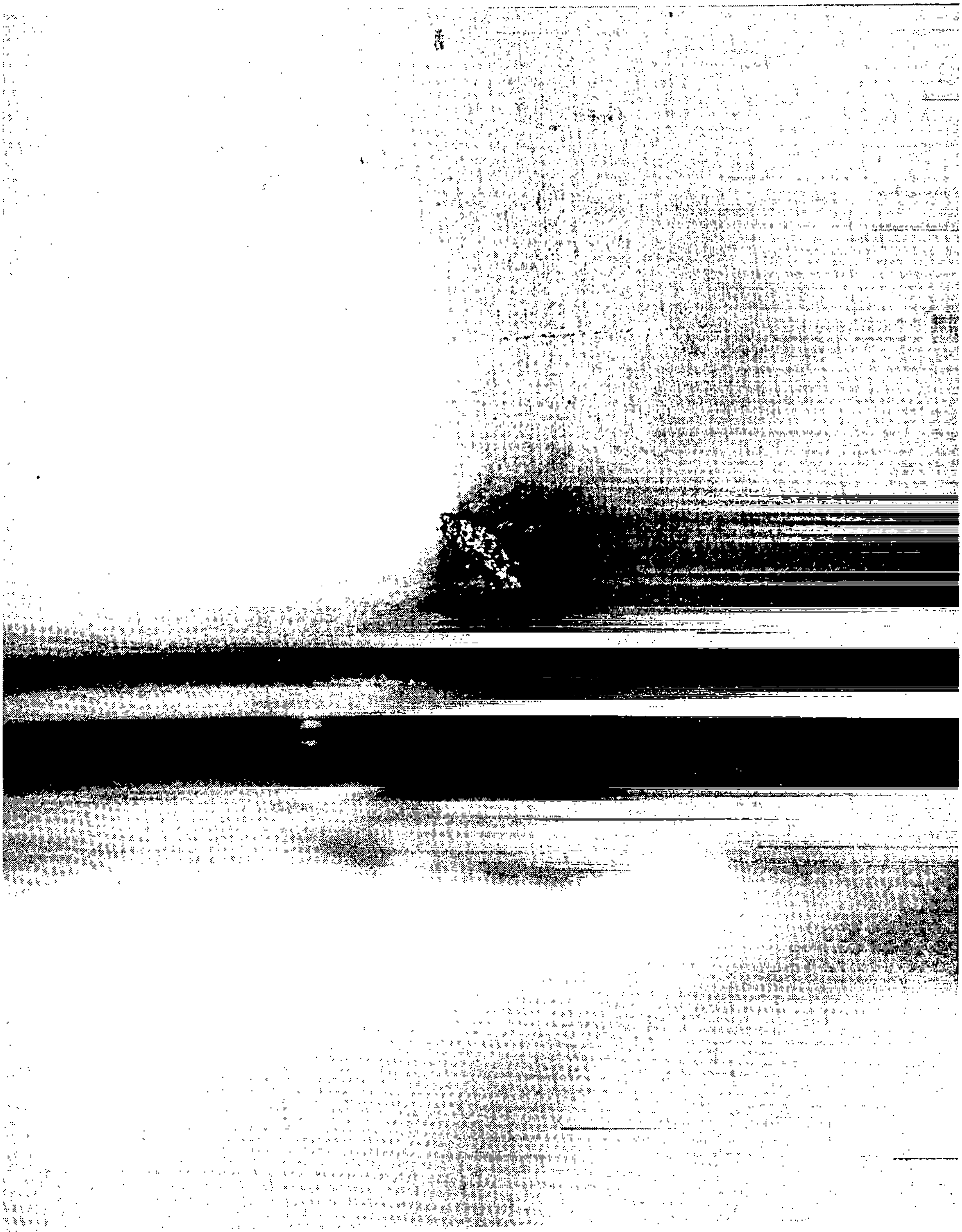


Figure 14. Photograph of an oblique feature on the experiment-tray flange of an A0178 tray. The complex inner morphology of this feature may indicate that it is the result of a multiple-impact event, or an impact from a poorly indurated particle. Note presence of associated (red) debris surrounding the impact site.

separated by ~100 μm thick Dacron netting. There was also one MTB in Bay B10 (S1005) which consisted of 8 to 10 layers of ~5 μm thick aluminized Mylar separated with Dacron netting and encased with an outer covering of Teflon-coated fiberglass cloth (beta cloth). An additional multi-layer structure which covered the entire experimental surface area of Bays B04 and D10 (A0054) consisted of an outer layer of aluminized Kapton followed by bonded layers of conducting epoxy, aluminum, non-conducting epoxy, and Kevlar.

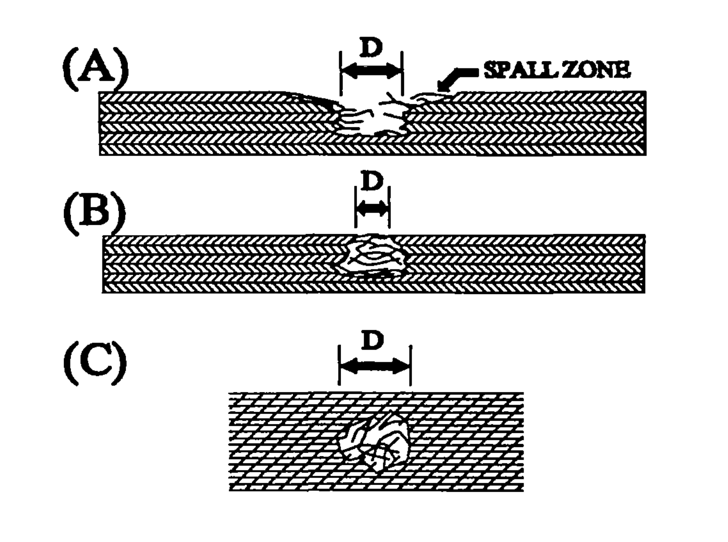


Figure 15. Illustration of the general feature morphology and associated feature diameter for features residing in composite structures. (A) Cross-sectional view of feature with surrounding spall zone, (B) feature with a larger damage zone, beneath the composite surface, than is visually seen at the original material surface, and (C) top view of a feature in a composite surface. Note the overlapping of the entrance hole by fibers of the composite material.

Large impacts into MTBs produced a "normal" penetration hole in the exterior layer (Figure 1c), followed by successively larger diameter holes in subsequent layers caused by the expanding debris cloud. The bottoms of the large impacts were rarely visible from the top of the assembled MTB. However, the last affected layers in the smaller events, which only penetrated 2 or 3 layers, often could be seen. Many features were imaged several times with different layers of the penetration holes in focus. In all cases, the hole diameter in the outer foil was measured as described above. Image files and tray-summary reports often contain measured diameters for the penetration holes through subsequent layers of the MTB when they were visible.

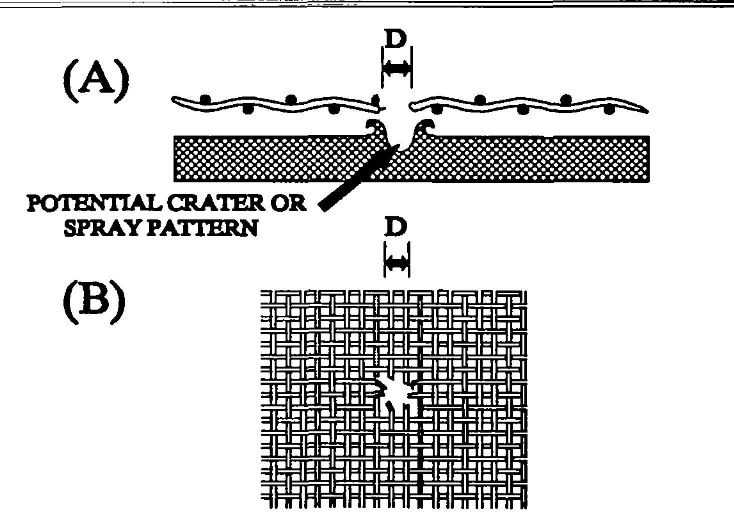


Figure 16. Illustration of the general morphology and associated diameter of features documented within fiberglass beta-cloth materials. (A) Cross-sectional view with potential crater or spray pattern underneath the beat-cloth layer and (B) top view.

Shadow images of the Dacron netting were present on impact affected areas of many of the secondary and tertiary films in the MTBs. This shadowing effect was the result of the Dacron netting shielding the lower layers of the films from debris-induced damage. Secondary craters and penetration holes often surrounded this shadowed netting image. Several instances of this characteristic were photodocumented on MTB surfaces, and descriptions of these features are included in the associated individual tray-summary reports.

Impacts into the beta-cloth blanket material were similar in many respects to penetration holes in the fibrous composite materials. The predominant observable impact-induced damage was the rupture of the fibers. The

frayed and pliable edges of the fibers around the impact site generally overlapped the penetration hole (Figures 16a and 16b), and it was not possible to see below the beta-cloth layer of this type of MTB. In addition, as a result of the few-hundred-micron yarn diameter and weave spacing, it was difficult to visually detect very small impacts into these beta-cloth surfaces. All penetrations which were detected in the beta-cloth surfaces (minimum size ~0.2 mm) were imaged. Feature diameters were measured from the apparent edges of the disrupted fibers on opposite sides of the hole.

Impacts into the A0054 multi-layer structures produced penetrations through different numbers of layers of the laminated structure. Feature diameters were measured from the center points on opposite sides of the crater rims, as shown in Figure 1c. Penetration-hole diameters through the various bonded layers were noted and included in the comments field of the associated image files. A variety of delamination and spall zones, and areas of foil which were peeled back, were present around several of the large impact sites. These are described in the associated tray-summary reports.

2.C SURVEYING PROCEDURES

Following the rendezvous of the Shuttle *Columbia* with the Long Duration Exposure Facility (LDEF) on January 12, 1990, the M&D SIG preformed various inspections or surveys of the LDEF spacecraft. The first two of four cursory inspections were conducted from the Johnson Space Center (JSC) by monitoring the recovery activities *via* close-circuit television, and by examining the negatives from the on-orbit photographic survey which was carried out by *Columbia's* crew following the recovery of, but prior to the berthing of LDEF within the payload bay. All remaining inspections were performed at the Kennedy Space Center (KSC) with the first of these occurring at the Orbiter Processing Facility (OPF) prior to the removal of LDEF from *Columbia's* payload bay. The final cursory inspection took place in the Operations & Checkout (O&C) building during the transfer of LDEF from the payload canister to the LDEF Assembly and Transportation System (LATS). Subsequent to the arrival of LDEF at the Satellite Assembly and Encapsulation Facility #2 (SAEF II), the payload processing facility in which LDEF was completed deintegrated, six additional, extremely detailed surveys where performed on the spacecraft as a whole, or on various discrete components prior to, or immediately after their removal from the spacecraft. These detailed examinations include the (1) Bolts, Clamps, Shims, and Experiment Tray Flanges/Lips Inspection and Bolt Orientation survey, (2) General Experiment Tray Front- and Backside survey, (3) Detailed Experiment Tray survey, (4) Thermal Panel Inspection and Bolt Orientation survey, (5) Detailed LDEF Frame survey, and (6) Detailed Thermal Panel survey.

2.C.1 ON-ORBIT SURVEY

The M&D SIG was involved in two preliminary surveys which occurred during the LDEF retrieval operations. The first of these took place at JSC during the actual LDEF retrieval operations on January 12, 1990. The downlink video and audio signals from the Space Shuttle *Columbia* were provided to the LDEF Inspection Team, which included a member of the M&D SIG, for continuous monitoring of retrieval activities. The survey was performed by watching the downlink signals on a large screen television in the Video Teleconferencing Center in Building 8 at JSC. The significant observations made during this survey were (1) the partial detachment of the Bay H03 and H12 (M0001) thermal blankets, (2) the presence of large amounts of orbital debris in the vicinity of LDEF, including a small solar panel which had detached from one of the experiments, (3) numerous thin-foil samples which had detached from one end of their holders, (4) extensive discoloration, contamination, and erosion of experiment samples, thermal blankets, fiber-optic bundles, and both anodized and painted aluminum surfaces, (5) the discovery that the A0187-1 clamshells were open when they should have been closed, (6) the presence of a large number of dark circular features on the various thermal blankets, and (7) the partially closed carousel of the S0069 experiment occupting Bay A09.

The first two observations were initially considered as a possible source of danger to the space shuttle, with the detachment of the thermal blankets generating the most concern since its causes was unknown. The orbital debris spotted in the vicinity of LDEF was mostly very small and was traveling with the two spacecraft

(as LDEF was the debris source), and was determined to present little danger to the space shuttle or its crew during the rendezvous with LDEF. After discussions with the M0001 experiment Principal Investigator (PI), it was determined that the most likely cause of the thermal-blanket detachment was thermal cycling and ultraviolet-light embrittlement of the Mylar tape used to attach these blankets to the experiment, but the actual cause is still under investigation.

Observations 3, 5, and 6 were of particular interest to the M&D SIG. The A0187-1 and A0187-2 experiments were dedicated meteoroid and debris experiment. The malfunction of the system on the A0187-1 experiment might have jeopardized the data collected (this turned out not to be the case), while the apparent erosion of the A0187-2 thin foils was of concern for these detector cells. The dark circular features on various thermal blankets were most likely impact related, but were larger in size and number than had been expected.

The second survey was also performed in Building 8 at JSC, and presented an opportunity to view the photographic survey of LDEF taken by the crew of *Columbia* during the retrieval and berthing operation of the LDEF spacecraft. This survey was conducted on January 21, 1990 after the shuttle had landed at Edwards Air Force Base. The astronauts were also present, so this provided an opportunity to ask them questions concerning the retrieval of LDEF, and for their personal observations of the LDEF spacecraft. While the pictures provided very little additional information, the discussions with the astronauts provided some interesting insights. According to the astronauts, LDEF continued to generate debris throughout the mission following its retrieval. This was most noticeable when the crew exercised within the shuttle's crew cabin. In addition, a misfiring of an attitude-control thruster, while the astronauts were sleeping, caused the shuttle to go into a flat spin for approximately ten minutes, exposing surfaces to the atomic oxygen flow which had not been previously exposed to this environment.

2.C.2 ORBITER PROCESSING FACILITY SURVEY

The next opportunity to examine LDEF was after the Space Shuttle *Columbia* had been ferried to KSC, demated from the NASA 747, and moved into the OPF. The OPF is a large clean room used for pre- and post-mission processing of the space shuttles and their payloads. On January 31, 1990, the LDEF Inspection Team was present in the OPF to monitor operations for possible movement-related damage to LDEF. LDEF was first surveyed while in the shuttle's payload bay where only Rows 1, 2, 10, and 11 could be surveyed from close range. Portions of Rows 3 and 9 were also visible, while Row 12 could be seen only from a distance of ~30' (~9 m). This survey identified the circular features on the thermal blankets as penetration holes surrounded by dark-colored rings.

Prior to removing LDEF from the shuttle's payload bay, the trunnion pins were surveyed by OPF operations personnel for impact features which would be damaged or destroyed during the installation of the trunnion-pin caps. No such features were found, nor was there any evidence of damaged features during later detailed surveys. The LDEF and Syncom VI-related hardware were removed from the shuttle's payload bay and transferred into the a payload canister without incident. Following the removal of LDEF from the shuttle's payload bay, the payload bay was cleaned by OPF operations personnel. The largest piece of LDEF hardware recovered during this cleaning was an ~4" x 4" (~10 x 10 cm) solar panel.

2.C.3 OPERATIONS & CHECKOUT SURVEY

After leaving the OPF, the payload canister containing LDEF and the Syncom VI-related hardware was moved to the O&C building (another large payload processing clean room) for further post-mission processing. Within O&C, LDEF was transferred from the payload canister to LATS on February 1, 1990. Again, the LDEF Inspection Team was present to monitor operations for possible movement-related damage to LDEF. Once in LATS, much of the spacecraft was surveyed at a close distance for the first time. This survey permitted full access to Rows 3 and 9, as well as Rows 4, 5, 7, and 8 (Row 6 could not be seen). The primary observation made during the transfer and post-transfer survey dealt with the generation of a large number of thin (~0.1 μm thick) aluminum-foil contaminates (primarily from Tray F09). These thin pieces of foil were found floating in the air of the O&C building and, later, became a major source of contamination

within SAEF II. Following the enclosure of LDEF with LATS, the spacecraft was transferred to SAEF II (a class 100,000 clean room facility) for final deintegration.

2.C.4 BOLTS, CLAMPS, SHIMS, AND EXPERIMENT TRAY FLANGES/LIPS INSPECTION AND BOLT ORIENTATION SURVEY

The M&D SIG requested, and was granted permission to conduct a pre-deintegration, on-spacecraft inspection of all bolts, clamps, shims, and experiment-tray flanges to identify features of interest which could be damaged or destroyed by (1) the attachment of the experiment-tray covers, (2) the removal of the experiment trays and clamps from the spacecraft, and (3) securing the experiment trays within the experiment-tray rotators or stands (*e.g.*, Figure 17). In addition, the M&D SIG had planned to record the orientation of only those clamp bolts upon which features were discovered. However, at the request of the LDEF Project Office, this effort was expanded to include every clamp- and thermal-panel bolt on the entire spacecraft.

On February 5, 1990, an M&D SIG member crawled underneath the spacecraft (Row 6) to inspect the areas of LDEF which were used to lift (*i.e.*, jack) the spacecraft into position for configuration into its rotatable mode. The purpose of this survey was to insure that no features of interest to the M&D SIG would be damaged or destroyed during these operations. No major discoveries were found, but it was the first opportunity to closely view Row 6.

Several pieces of LDEF hardware had to be removed from the spacecraft prior to the first detailed M&D SIG surveys in order to place LDEF into its rotatable configuration on LATS. The pieces of hardware which fall into this category included the two Earth-end trunion-pin scuff plates, the Earth-end walking beam and trunion pins, and thermal panels G19 and H19. However, this hardware was examined in detail by members of the M&D SIG following its removal from the spacecraft. In addition, the layered thermal blankets of the Heavy Ions in Space experiment (M0001; Bays H03 and H12) had to be removed or taped down by the experiment PI so that LDEF could be rotated without causing further damage to these surfaces. These latter items were examined in detail prior to, and following their removal from the spacecraft.

The numbering scheme utilized by the M&D SIG for hardware identification was a slightly modified version of the one adopted by the LDEF Project Office prior to the flight of LDEF. In short, the LDEF spacecraft was a 14-faced (12 sides and two ends), open-grid structure on which a series of rectangular trays used for mounting experiment hardware were attached. The original numbering scheme for the spacecraft grid was established where components were identified using "Bay" and "Row" numbers (*e.g.*, A03; Figure 18). In view of the original scheme not providing a process by which hardware other than the experiment trays could be numbered, the M&D SIG expanded on the original numbering scheme to include the end grids by assigning row numbers in a clockwise (Earth-facing end) or counter-clockwise (space-facing end) direction. In this way, unique bay- and row numbers could be assigned to other LDEF hardware (*e.g.*, H15 for one of the space-end thermal panels) which, like the original scheme, provided information about the hardware's location on the spacecraft.

For similar reasons, a numbering scheme was devised by the M&D SIG for the various clamps, bolts, and shims which would provide information related to the hardware's location on the spacecraft, as well as with respect to its location within a particular bay. The experiment trays were affixed to LDEF by a series of clamps (some of which contained paint samples; see Figure 19); eight clamps were used to attach the experiment trays on the 12 sides of LDEF, while experiments occupying the two ends were held in place by 12 clamps (Figure 19). From the numbering system outlined in Figure 19, it can be seen that a clamp occupying position "6" of Bay A03 (Figure 18) would be identified by the number A03C06, with "A03" indicating the LDEF bay location and "C06" the clamp location with respect to Bay A03. Lastly, as there were only three bolts associated with each clamp, the bolts were assigned the letters A-C from either left to right, or top to bottom depending on whether the clamp was horizontal or vertical, respectively, in relationship to the bay (Figure 20).

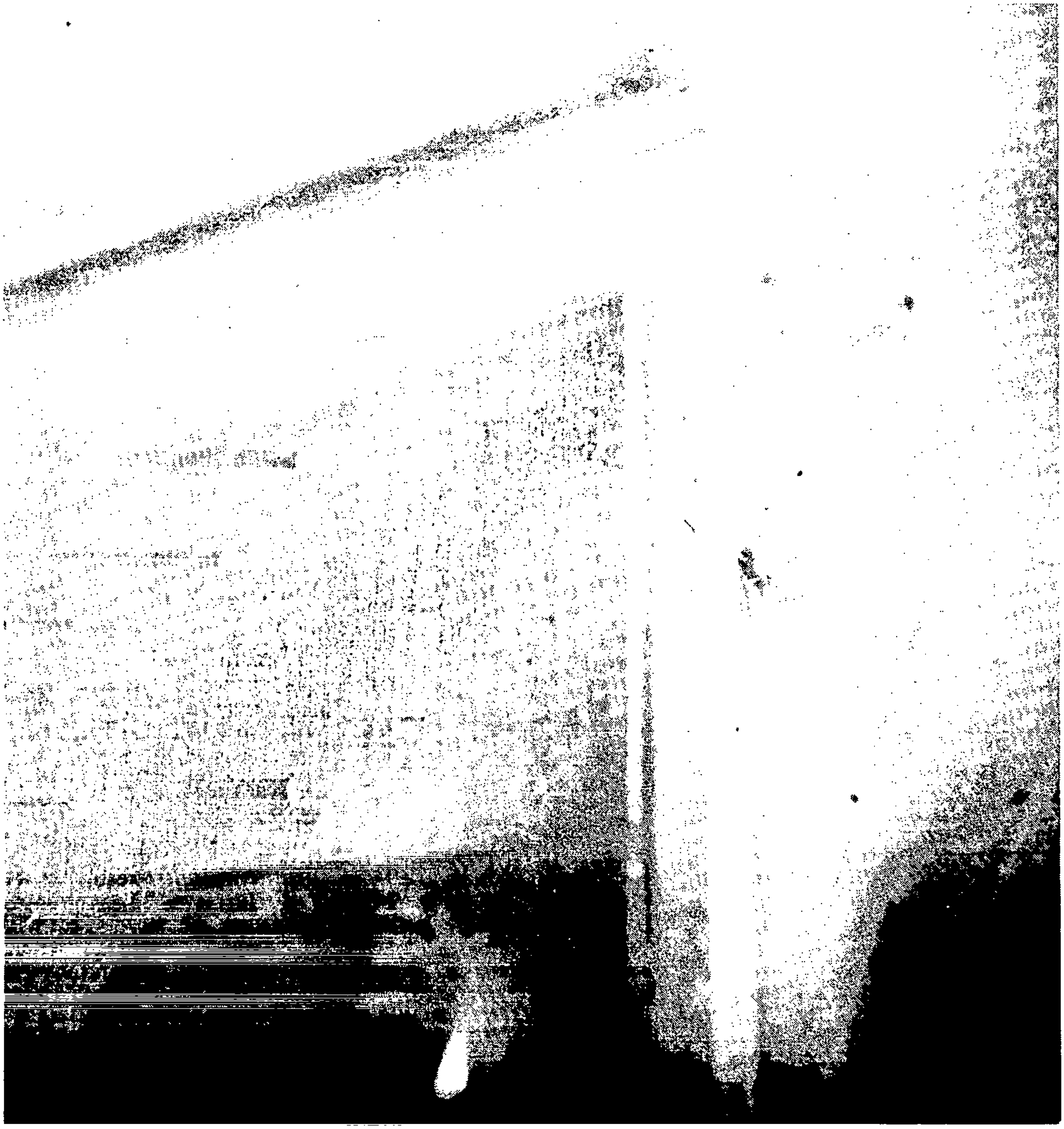


Figure 17. Impact (and associated debris) into the edge of a clamp shim. Features such as these which could be damaged or destroyed during the deintegration of the experiment trays from LDEF were one of the primary reasons for conducting the pre-deintegration survey.

Prior to conducting the on-spacecraft inspection and bolt orientation survey of the 88 experiment bays (86 actual experiment locations and two dummy-panel locations on Bay G), the M&D SIG produced maps of all bays on the LDEF spacecraft, including the uniquely-shaped Earth- and space-ends corner bays. These maps included information pertaining to the bay location, the experiment number, the date, and drawings of each clamp and its associated bolts (Figure 20). A scheme was devised where a feature of interest would be marked on these maps with an "x" in the approximate relative position on the appropriate piece of LDEF hardware; features residing on the side or edge of an LDEF component were to be indicated with an "↑". Lastly, the orientation of all clamp bolts would be recorded with a "•" on the corresponding bolt of the experiment map.

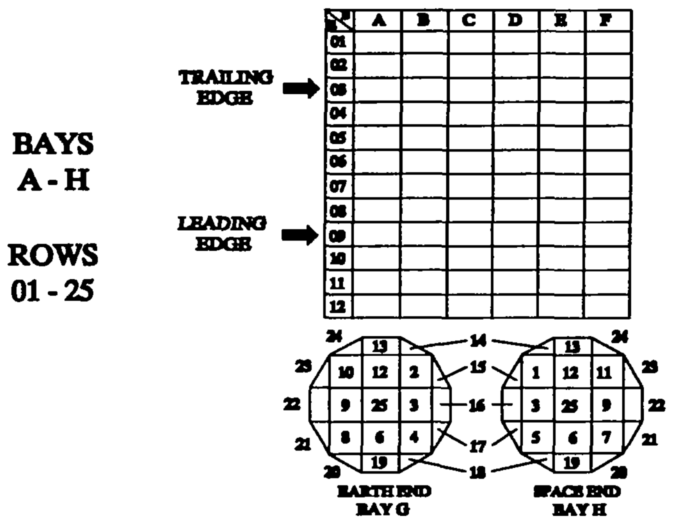


Figure 18. Diagram illustrating the expanded numbering scheme adopted by the M&D SIG to permit assignment of unique identification positions to all LDEF hardware.

On February 20-23, 1990, prior to the removal of the first experiment tray and its associated hardware (except for components of H03 and H12, see above), and before the experiment-tray covers were installed, members of the M&D SIG A-Team conducted the pre-deintegration inspection and bolt orientation survey of the 88 LDEF experiment bays (*i.e.*, Bays A01-H12). The survey was conducted one row at a time over the three day period by two teams of two people (one scanning and measuring, and one writing and recording). The typical sequence during this survey began by recording the bay location, experiment number, and date for each bay on a particular row. Next, the orientation of all clamp bolts was recorded by the surveying team member calling out the relative clock position (*e.g.*, 3:00, 7:30, etc.) of the "MA" which appeared on the top of each of the 303 stainless steel, hex-head clamp bolts (Figure 22; also see Figure 9), and the other team member recording the position with a "•" on the experiment map (NASA photograph KSC-390C-1190.06). During step three, the clamps, clamp bolts, and experiment-tray flanges were examined for the presence of features which could be damaged or destroyed during the tray deintegration process. When such features were encountered on the experiment-tray flanges, the distance (in millimeters) to the nearest experiment-tray cover bolt hole was determined *via* a metric scale (Figure 21, also see NASA photographs KSC-390C-1190.02 and KSC-390C-1190.12). The recording team member would then mark the appropriate location on the experiment map with an "x", number it, and record the distance information by the corresponding number in the "Feature Location" column (Figure 20). Identical marks were registered on the maps for features residing on the various clamps or clamp bolts. Following the completion of this survey for each bay, the map (form) was signed-off by the M&D SIG. When all bays on a particular row had been completed, the forms were given to the appropriate Quality Assurance personnel. The original forms now reside in the Curatorial Facility at JSC.

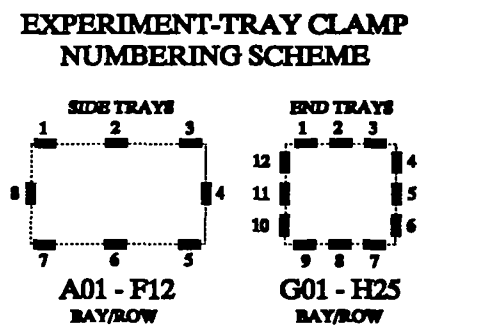


Figure 19. Diagram showing the clamp numbering scheme utilized by the M&D SIG for the peripheral- and ends bays of the spacecraft.

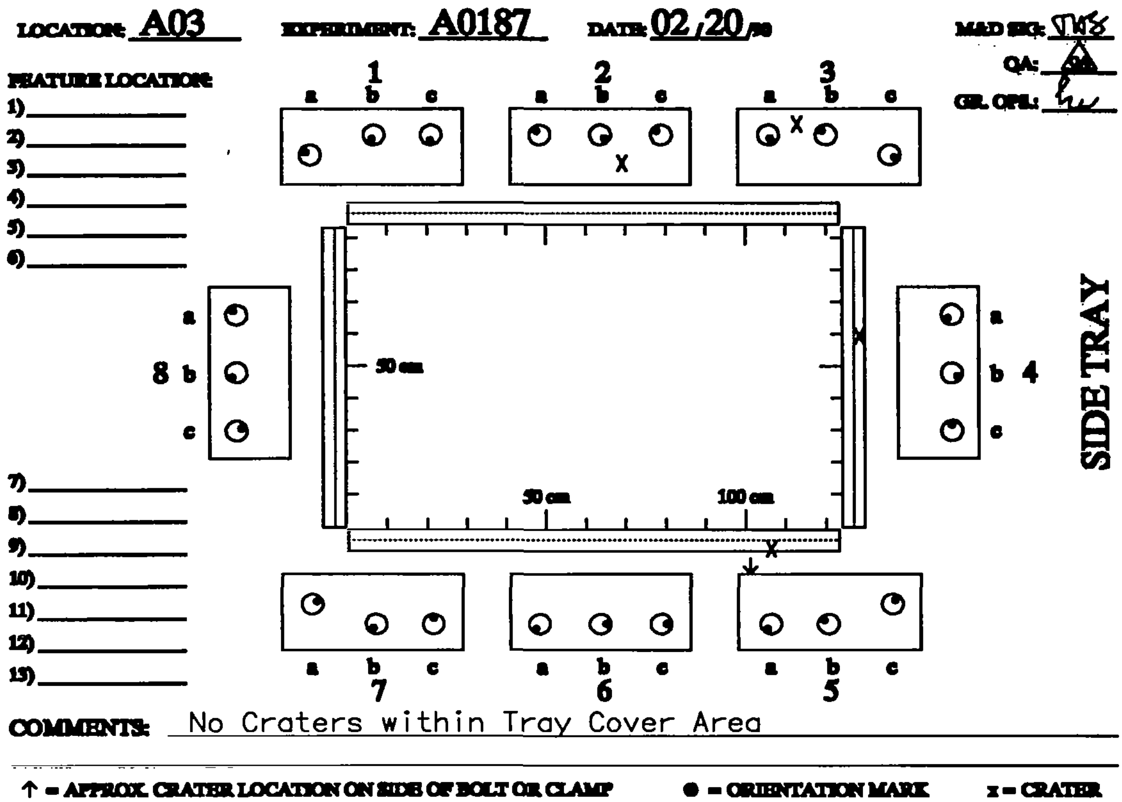


Figure 20. Example of an M&D SIG Experiment/Bay Map used during the on-spacecraft inspection for recording the location of features of interest and for documenting the orientation of all clamp bolts.

The final step of the on-spacecraft inspection involved cutting a small section out of the rubber experiment-tray cover gasket in those places identified by the M&D SIG which could damage features of interest. Permission to make these cuts was sought from each experiment PI, and in most cases was granted. The actual gasket cutting took place in the outer air-lock of SAEF II and was carried out by M&D SIG- and Ground Operation personnel working in unison (Figure 23, also see NASA photographs KSC-390C-1214.03). The exact location to cut the gasket was measured from the experiment-tray cover bolt hole nearest to the feature (see above). A small section of the gasket was then removed with a scalpel from either the inner, central, or outer portion of the gasket strip. By not trimming the gaskets across the entire cover-gasket strip, the experiment-tray cover could still seal with the experiment-tray flange preventing contamination from reaching the experimental surfaces. Once this task was completed, the individual experiment-tray covers were attached to the appropriate bay location by Ground Operation personnel.

The above sequence of events was repeated for all 12 rows of the LDEF spacecraft, including the Earth- and space-facing ends. During the removal of the various experiment trays from the spacecraft, Ground Operations personnel would reference the appropriate map/form to determine if special tools (*e.g.*, open-end wrench) or handling procedures were needed during the deintegration operations to avoid damage to a feature which had been identified by the M&D SIG.

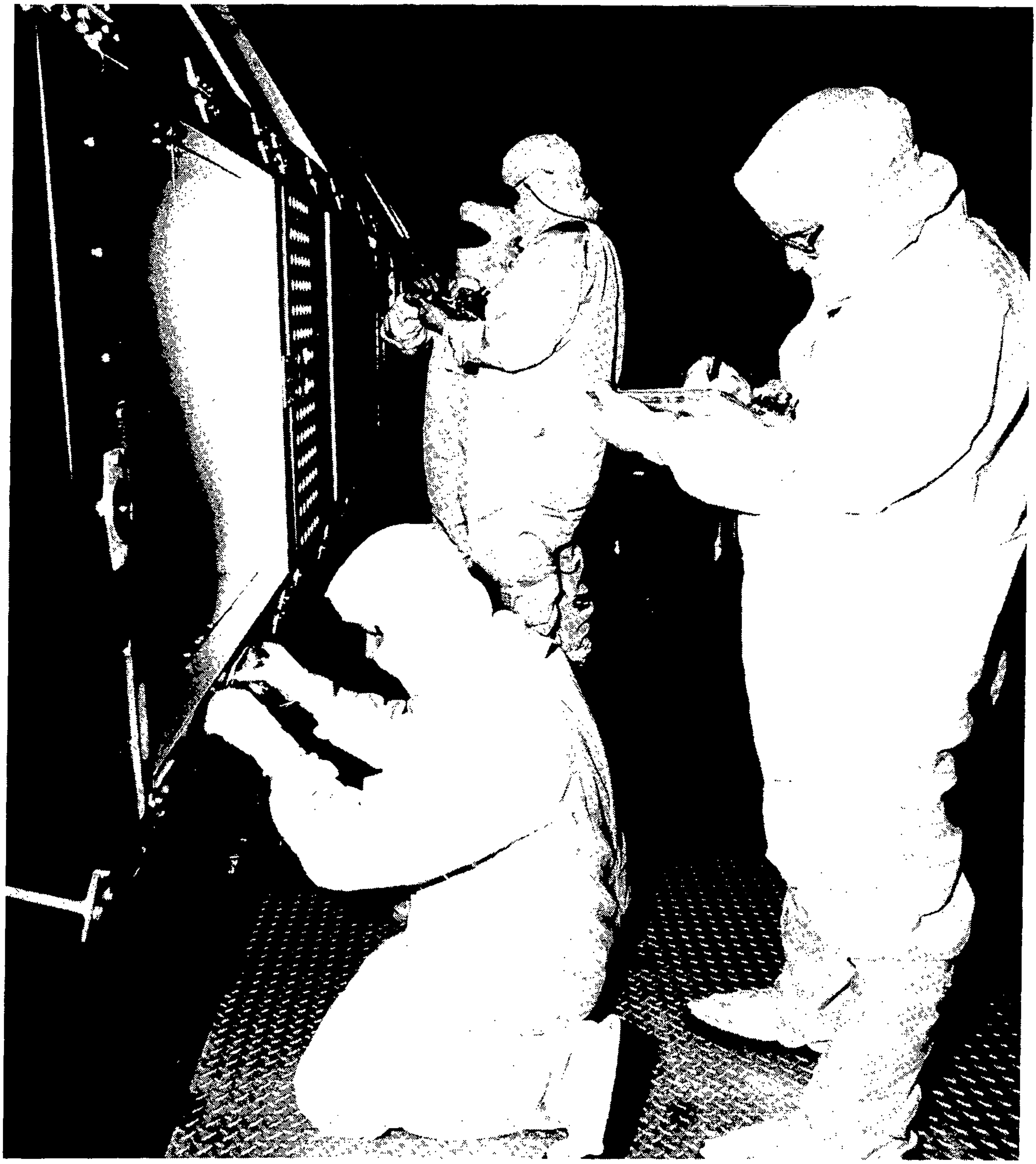


Figure 21. Members of the M&D SIG performing the BOLTS, CLAMPS, SHIMS, AND EXPERIMENT TRAY FLANGES/LIPS INSPECTION AND BOLT ORIENTATION SURVEY prior to the commencement of the deintegration oeprations.

2.C.5 GENERAL EXPERIMENT TRAY FRONT- AND BACKSIDE SURVEY

BOLT ORIENTATION

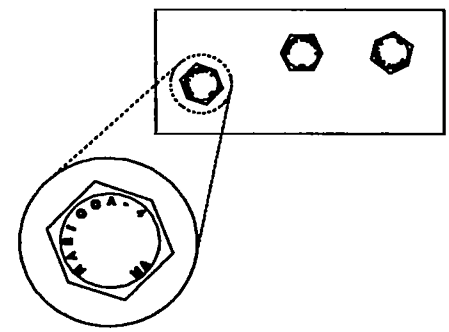


Figure 22. Illustration of the fiducial mark "MA" utilized by the M&D SIG for documenting the orientation of the experiment-tray clamp bolts.

As an integral part of the tray removal operations, which began following the installation of all experiment-tray covers, the M&D SIG performed several detailed inspections of the experiment trays as they were processed. The first of these inspections was the General Front- and Backside survey of the experiment-tray flanges and back surface. While the experiment tray was suspended from the overhead crane an M&D SIG member performed the inspection by first looking at the backside of the experiment-tray flanges for phenomenon related to front-surface impacts (*e.g.*, bulges, spallation effects, penetration and ejecta effects) which could be damaged or altered by the experiment-tray rotator clamping mechanism. When found, these features were photodocumented prior to placing the experiment tray within the rotator. Next, the back surface of the experiment tray was examined for anything unusual (*e.g.*, back-surface impacts, outgassing stains, discoloration, etc.). Following the completion of this inspection the findings of the surveyor were entered in the *Summary Books* kept by the M&D SIG A-Team throughout their KSC operations.

Subsequent to the completion of the Front- and Backside survey, each tray was placed within one of the three LDEF- or three JSC rotators for purposes of examination, photography/documentation, and any KSC-required deintegration related efforts. Within the LDEF rotators, trays were held in place by two pairs of aluminum angles which would squeeze the side experiment-tray flanges between them (see Figure A01-1), while in the JSC rotators trays were affixed by clasping the flanges between six sets of aluminum plates (*i.e.*, two sets along each side, and one set each on the top- and bottom flanges; see Figure A03-1). In both rotator types the trays could be rotated through a full 360°. Following the installation of a tray within a rotator it would proceed to either the LDEF/KSC photography session in the small-equipment air lock, or the detailed scanning and photodocumentation conducted by the M&D SIG.

2.C.6 DETAILED EXPERIMENT TRAY SURVEY

The M&D SIG utilized three small areas within the passageway to the oven of SAEF II to conduct their detailed examination and documentation of all LDEF hardware; each of these areas was equipped with a Coordinate Registration- (CRS) and Stereo-Microscope Imaging System (SMIS; see Section 2D for information pertaining to the SMIS). Two of the three stations (Systems #1 and #2) were used primarily for examination and photodocumentation of individual experiment trays, while the third station (System #3) was primarily utilized for examination and photodocumentation of miscellaneous LDEF hardware (*e.g.*, bolts, clamps, shims, reflectors, etc.).

Suspected impact features which met the minimum size requirements of 0.3 mm in diameter for penetration holes or 0.5 mm in diameter (center-of-rim to center-of-rim; see Section 2B) for craters, or smaller features which exhibited some interesting characteristic (*e.g.*, secondaries, associated debris) were visually identified on the experiment tray- or subcomponent surface and their coordinates recorded prior to imaging. Two methods (electronic and manual) were utilized by the M&D SIG for feature coordinate determination. The primary reasons for registering the coordinates of features were to (1) assure the ability to relocate individual features at some later date and (2) document location information which would permit geographical plotting and analyses.

Figure 23. M&D SIG and Ground Operations personnel removing small sections of the experiment-tray cover gasket to prevent damage and contamination to features residing on the experiment-tray flanges.

2.C.6.a The Coordinate System

With the exception of a few miscellaneous pieces of LDEF hardware (*e.g.*, walking beam, scuff plates), all X- and Y-coordinates were measured (in millimeters) in a Cartesian coordinate grid system (positive or negative) from the standard (0,0) reference point assigned by the M&D SIG. In addition, many experimental surfaces exhibited various degrees of relief, or resided within a 6"- or 12"-deep (15.2 or 30.5 cm) tray. On such surfaces the distance of features below the experiment-tray flanges, as well as any photodocumented features residing on the inner-tray walls, were assigned positive Z-values; correspondingly, features located on surfaces protruding above the experiment-tray flanges were assigned negative Z-values. Unusually shaped hardware, such as the walking beam and scuff plates, were assigned unique (0,0) reference points which are fully described in the appropriate summary report. For these odd-shaped LDEF components a Cartesian grid was partially abandoned in favor of a more logical system, such as a radial Y- and a linear X-coordinate.

The standard adopted by the M&D SIG for orienting hardware removed from LDEF was to place the component (*e.g.*, experiment tray, thermal panel, clamp, etc.) in the position or orientation which it was in at the time of deintegration from the spacecraft. For peripheral experiment- and grapple-fixture trays the up direction or top flange was defined as the flange which was adjacent to the bottom flange of the experiment tray in the next lowest row on LDEF. For example, the top flange of an experiment tray which was removed from Row 5 was adjacent to the bottom flange of the experiment tray in the corresponding Row 4 bay. The top flange of Row 1 trays was defined to be the flange adjacent to the bottom flange of the corresponding Row 12 tray. In addition, prior to the flight of LDEF, the bottom flanges of all experiment trays were stamped with an identification code. For 3"-deep (7.6 cm) trays this identification code was located on the right side of the flange, while for 6"- and 12"-deep (15.2 and 30.5 cm, respectively) trays the identification code resided on the left side of the bottom flange. Similarly, the top flange of Earth- and space-end experiment trays was defined as the flange which was at the top of the tray as they were positioned for deintegration from the spacecraft; like the peripheral trays, the end trays were stamped with an identification code which was located to the left of center on the bottom experiment-tray flange.

The general location of the (0,0) reference point for all experiment trays was defined to be the lower-left corner at the intersection of the left- and bottom experiment-tray flanges (Figure 24). For all but few experiment trays, the (0,0) reference mark was placed on the bottom of the left flange at the point where the flange curved 90° to form the inner-tray wall (Figure 25a). End trays G04 and H05 differed from all other trays in that they did not possess a 90° intersection of the left- and bottom experiment-tray flanges. Instead, a 45° corner flange occupied this general position on the experiment-tray flanges which were housed within these two bays of LDEF. For these trays the (0,0) reference mark was placed on the bottom of the left flange were it intersected with the 45° corner flange (Figure 25b). The actual fiducial mark was made by placing a dot of either black or red indelible ink on the experiment-tray flange in the positions indicated in Figures 25a and 25b. Exceptions to this rule were brought about by the experiment PI requesting that a particular tray or component not be marked. In such cases an impact feature or other visible mark on the experiment-tray or subcomponent was used as the (0,0) reference point, and is discussed in the corresponding summary report. For small subcomponents, such as experiment-tray clamps, bolts, and shims, the corners were not marked since their position was unmistakable and their absolute dimensions very small.

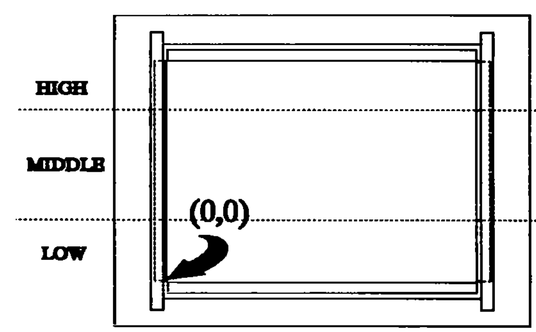


Figure 24. Diagram illustrating the general location of the (0,0) reference point at the intersection of the left- and bottom experiment-tray flanges. The horizontal dashed lines represent the three zones (High, Middle, and Low) in which photodocumentation of features was divided due to limitations of the Stereo-Microscope Imaging Systems.

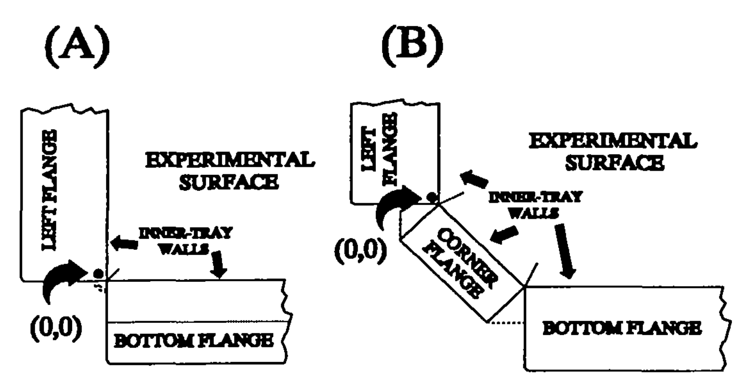


Figure 25. Diagram illustrating the location of the (0,0) reference mark on the lower portion of the left experiment-tray flange for (A) typical peripheral- and end experiment trays and (B) Trays G04 and H05 which possessed a 45° corner flange at the lower left corner of the experiment tray.

Earth- and space-end thermal panels were treated in a similar manner as were the experiment trays on the corresponding end of the spacecraft. The top surface or edge was defined to be the uppermost edge as the individual panels were positioned for deintegration from the spacecraft. The 24 thermal panels were roughly triangular or rectangular in shape and were marked in the appropriate lower leftmost corner. Space-end thermal panels received a fiducial mark of either black or red indelible ink, while the black anodized Earth-end panels were marked with a dot of silver paint. As a result of the unusual shapes and orientations of these panels, examples of the six orientations and their associated (0,0) reference points are illustrated in Figure 26; the approximate location of the (0,0) reference points for each thermal panel is illustrated in the appropriate thermal-panel summary. Thermal panels G19 and H19 were not referenced using this standard scheme as they were among the first pieces of LDEF to be removed and examined by the M&D SIG. The location of the (0,0) reference point for these two panels can be found with their associated summary reports.

The (0,0) reference point for features identified on the LDEF structural components (*i.e.*, longerons and intercostals) were assigned utilizing the criteria as were discussed with the experment trays and thermal panels, above. Details associated with the LDEF frame survey can be found in Section 2.C.9 and will not be discussed here.

2.C.6.b Electronic Coordinate Registration System

Three identical electronic coordinate registration systems were fabricated from off-the-shelf components by Prototype Machine Corporation, St. Louis, Missouri. The systems consisted of electronic linear spars (Mitutoyo AT11N) which were mated to drafting system sliding tracks (Vemco V-track 630) and fitted with custom fabricated, adjustable-height 3x spotter scopes. The upper and lower lenses of the spotter scopes were etched with a crosshair and 1.0 mm circle, respectively; the lenses were physically separated by several cm. This lens arrangement prevented positioning errors due to parallax by allowing the crosshairs to be reliably repositioned in the center of the circle. The signals from the electronic spars were displayed on a digital readout unit (DRO; Mitutoyo ALC-EC). Each of the three electronic CRSs was paired to one of the three LDEF experiment-tray rotators and assigned the same number (1, 2, or 3) as the rotator to which it had been mated. A CRS could also be mounted to a workbench, as was done at various times for feature coordinate determination on various LDEF components (*e.g.*, thermal panels) which were examined in the horizontal position.

The absolute accuracy and precision of the CRSs were measured when the systems were mounted on a workbench and on the experiment-tray rotators. A metric tape measure was affixed to the appropriate surface and the distance between points which were 100.0 cm apart were measured repeatedly, as well as the return to (0,0) values. Following determination of the errors associated with each system, dip switches within the DROs were set to compensate for appropriate range errors. Once the this compensation was set for each

system, positioning at the extremes (*i.e.*, maximum X and Y) of the system's coverage area were tested. Precision of all scales over the 100.0 cm distance was within 0.2 mm, while overall accuracy was within 0.5 mm.

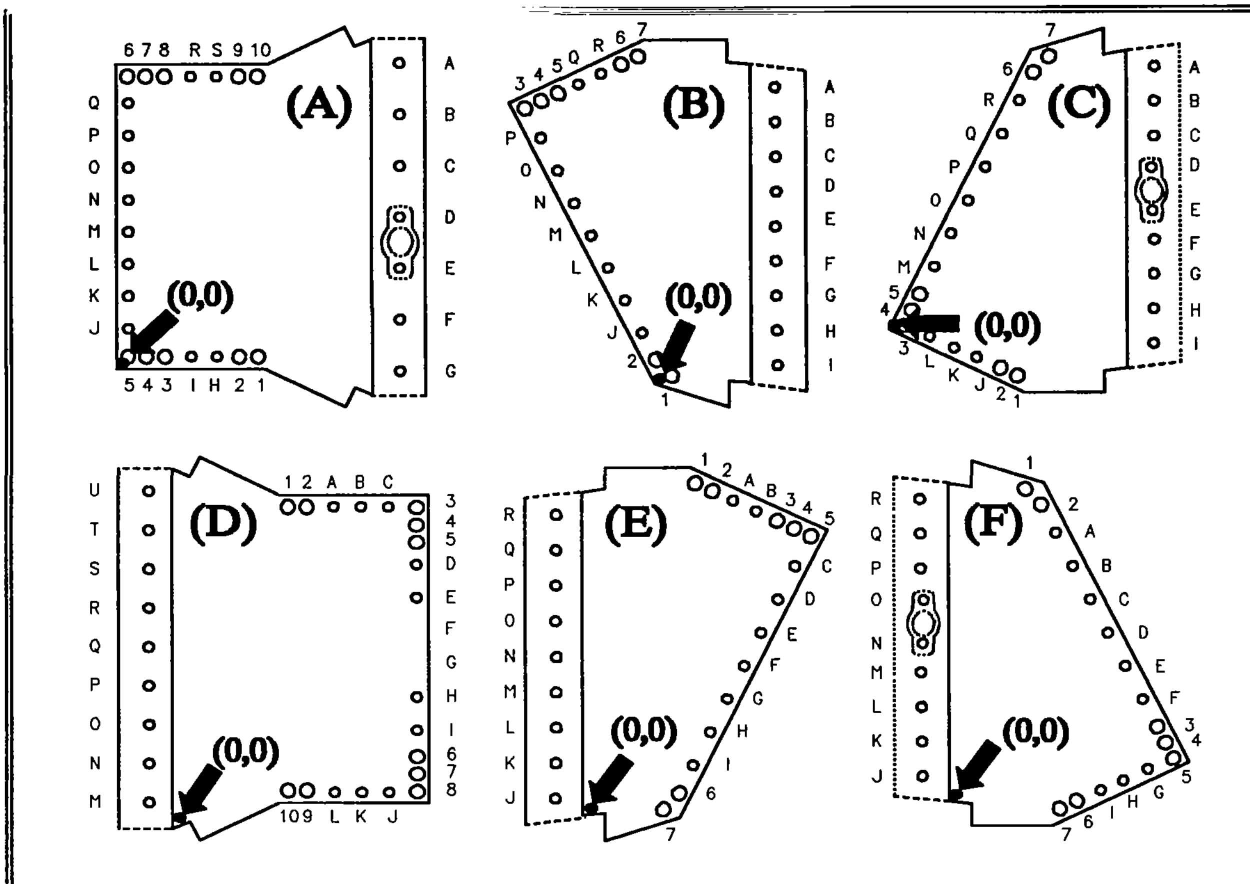


Figure 26. Examples of the shape, orientation, and location of the (0,0) reference point for Earth- [A-C] and space-end [D-F] thermal panels. (A) G13, (B) G14, (C) G15, (D) H16, (E) H13, and (F) H14. The locations of reflectors for these panels are also shown.

2.C.6.c Manual Coordinate Registration Systems

Experiment trays which arrived in the M&D SIG area for examination residing on one of the three JSC rotators could not utilize one of the CRSs due to the rotator's tubular-frame design In addition, all of the S0001 3"-deep (7.6 cm) experiment trays (except B08) were examined and photodocumented in the horizontal position on either a workbench or rollable table precluding the use of a CRS. In such cases, and in other instances (*e.g.*, on most small subcomponents [clamps, bolts, shims, reflectors, etc.] and on the LDEF frame), a metric tape measure or scale was used to determine the coordinates of potential impact features.

For small components the relative accuracy of manually determined coordinates is approximately ±2 mm. On large and/or complex surfaces (like an irregular thermal blanket) the relative accuracy of manually determined coordinates varied. The overall average is stated to have been ±5 mm. This higher value is due to the (1) reproducibility of measurements using the tape measure or scale, (2) requirement of no physical contact with LDEF surfaces, and (3) different personnel who participated in the M&D SIG photodocumentation efforts making the measurements. In some cases the accuracy error may be slightly larger, but in all instances the primary goal of feature relocation was maintained.

2.C.6.d Surveying Procedures

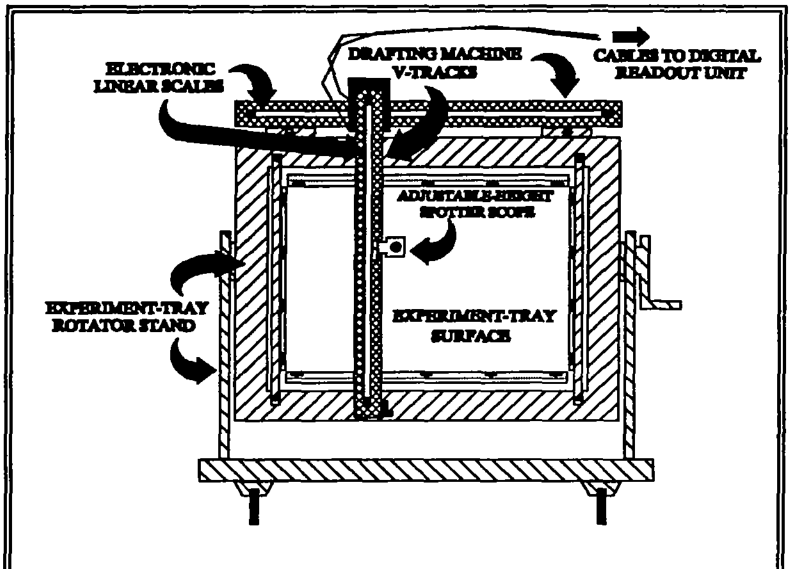


Figure 27. Schematic illustration of an M&D SIG Coordinate Registraion System (CRS) mounted on one of the LDEF rotators.

As an experiment tray entered the M&D SIG area it was moved to the first available documentation station (generally System #1 or #2). Following the removal of the experiment-tray cover by Ground Operation personnel, an M&D SIG member would initiate attachment of the appropriate CRS if the experiment tray resided on one of the LDEF rotators (the appropriate CRS was determined by the number of the LDEF rotator; see Section 2.C.6.b). Attachment of a CRS to an LDEF rotator was accomplished by first affixing the X-linear scale to a pair of aluminum blocks which had been fastened to the upper aluminum angle of the rotator. Once the X-axis system had been secured in place by large thumb screws, the Y-linear scale was coupled to the X-axis system by means of a clamping-lock mechanism (the bottom portion of the Y-axis system traveled along the lower aluminum angle surface *via* a wheel). The scale reader of the X-axis system was then attached to the Y-axis spar by means of two allen-head screws. The final step in assembling the CRS was to hook the output cables of both axes through a pair of rings which were attached to a spring, which in turn were fastened to the wall. The purpose of this hook and spring device was to provide sufficient tension to the cables so that they could not come into contact with the any space-exposed hardware or the back surfaces of the experiment tray (Figure 27 and NASA photograph KSC-90PC-330).

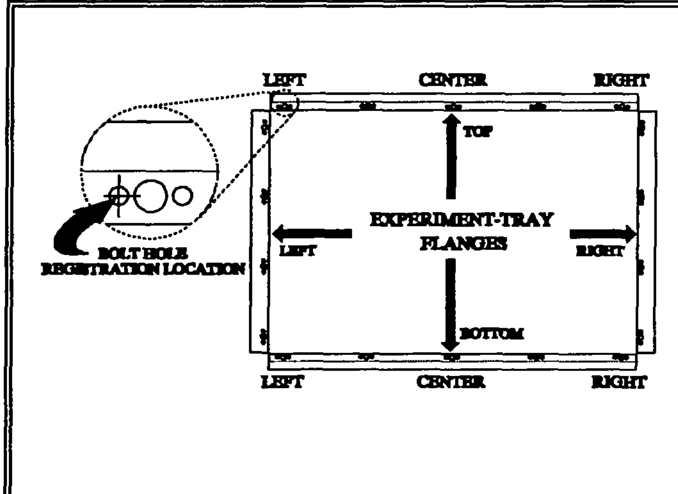


Figure 28. Illustration depicting the small machined holes to the left of the experiment-tray bolt holes on the experiment-tray flanges. During the detailed surveying and photodocumentation of many trays, the locations of these small holes were measured and recorded.

The surveying of all experiment-tray surfaces (*i.e.*, experiment-tray flanges and the experiment surface) for features to be examined microscopically and possibly photodocumented was conducted by two individuals (one surveying and one recording the appropriate information in a system logbook). To begin the survey a (0,0) reference mark was placed on the experiment-tray flange in the lower left-hand corner (see Section 2.C.6.a and Figures 24 and 25). If a CRS was being used for the survey, the spotter scope was moved to the (0,0) reference mark and the X- and Y-LEDs of the DRO were reset by pressing the appropriate buttons on the face of the DRO. Next, the coordinates of any fiducial marks on the component surface were then recorded. On experiment trays which were completely covered with an A0178 thermal blankets, an M&D SIG member would place a cross on the top and bottom of each third of the thermal blanket. The X,Y-coordinates of these fiducial marks were then measured and recorded. In addition, on these and several other experiment trays, the locations of the top- and bottom left, center, and right experiment-tray cover bolt holes were determined and recorded in the logbook (the bolt

holes themselves were not actually indexed, instead a machined hole to the left of each of bolt hole was the object documented; Figure 28). Following the registration of the six machined holes, the spotter scope was returned to the origin and the (0,0) reference point rechecked. If the values on the DRO fell within ±0.5 mm of the original (0,0) values, coordinate registration began on the experiment-tray flanges and exposed experimental surfaces. If the (0,0) rechecked exceeded this ±0.5 mm value the system was re-zeroed and the above process repeated.

Surveying operations of the experiment-tray flanges and experimental surfaces were commonly divided into three section or zones (top, middle, and bottom; see Figure 24) due to certain limitation of movement associated with the SMIS. All surfaces were scanned for features equalling or exceeding the M&D SIG photodocumentation threshold diameter (*i.e.*, ≥0.5 mm for features in solid surfaces and ≥0.3 mm for penetrations through thermal blankets or similar materials; see Section 2.B). When such features were encountered, their X,Y-coordinates were measured by sighting the object through the 3x spotter scope which was attached to the Y-axis spar of the CRS. Centering of the object within the spotter scope was accomplished by placing the feature in the center of the crosshairs and circle, simultaneously. Once accomplished, the coordinates for the feature were read from the DRO and recorded in the logbook along with the type of material in which the feature was located (if known), and any other pertinent information about the feature deemed appropriate by the surveying personnel (*e.g.*, presence of associated debris). Features identified during this survey which were obviously less than the applicable M&D SIG threshold diameter were recorded only as "Too Small"; no coordinates for such features were measured. Unfortunately, until approximately the third week of the M&D SIG photodocumentation operations, the distribution (*i.e.*, whether they resided on the experiment-tray flanges or the experimental surfaces) of these "Too Small" features was not recorded. Features which did not unquestionably fall into either the Too Small- or to-be-documented categories were entered as "borderline" within the logbook; the determination was then made *via* the detailed microscope examination which followed the completion of the survey. During the detailed microscope examination of the registered features, occasionally objects which were originally believed to represent impact-related phenomenon were found to have other origins. Therefore, while the counts for the "Too Smalls" are presented for most surfaces, their small size and number precluded the kind of close examination which would have verified their identity as actual impact features.

The entire experiment tray was scanned in this fashion prior to bringing the SMIS into position to closely examine and measure each indexed feature in detail. If the feature was determined to be of sufficient size following examination with the SMIS, or exhibited some particularly interesting characteristics, it was photodocumented by acquiring a pair of digitized stereo images (for details on imaging procedures and the associated equipment see Section 2.D). In short, each image was combined with certain alphanumeric information which was entered *via* a portable computer (LDEF bay location, experiment number [*e.g.*, A0187-1], component number [generally E00], the X,Y-coordinates, image magnification, rotator number, storage optical-disk number, and up to 120 characters of comments, including the estimated diameter) and stored on two separate laser WORM (Write Once, Read Many) drive systems. This redundancy of storing all images on two separate disks was undertaken to assure that no data could be lost due to the failure of a storage drive, or as a result of damage to an optical storage disk.

Following the completion of the M&D SIG survey and photodocumentation of an experimental tray, the tray was signed-off by an M&D SIG member, the experiment-tray cover was replaced by Ground Operations personnel, and the experiment tray was removed from the M&D SIG area to another location (*e.g.*, LDEF photography area, Materials SIG area, electrical checkout area). If the experiment tray held one of the sixteen A0178 experiments, or was the Seeds in Space experiment (P0004/P0006), it returned to the M&D SIG area following the LDEF/KSC photodocumentation and any other SIG-group examination for trisecting, removal, and packaging of the thermal blanket (see Section 2.E). The original survey records and digitized image files are now residing in the Curatorial Facility at JSC.

2.C.7 THERMAL PANEL INSPECTION AND BOLT ORIENTATION SURVEY

The second on-spacecraft inspection undertaken by the M&D SIG was the Thermal Panel Inspection and Bolt Orientation survey. This survey was conducted on March 29, 1990, and, like the previous on-spacecraft inspection of the experiment bays, was performed by two teams of two people from the M&D SIG group. As was the case for the previous inspection, the purpose of this survey was to identify features of interest residing on LDEF hardware (*i.e.*, thermal panels, reflectors, and thermal-panel bolts) which could be damaged or destroyed by the removal of the hardware from the spacecraft. Similarly, the orientation of all bolts securing this hardware to the spacecraft was documented using the procedures described in Section 2.C.4. Thermal-panel maps containing similar information to those produced for the previous survey (see Figure 20) were generated by the M&D SIG for use during this survey. During deintegration operations, Ground Operations personnel would reference the appropriate map/form to determine if special tools (*e.g.*, open-end wrench) or handling procedures were needed to avoid damage to features residing on the LDEF component which had been identified by the M&D SIG.

2.C.8 DETAILED LDEF FRAME SURVEY

The final on-spacecraft inspection performed by the M&D SIG was the Detailed LDEF Frame survey which was conducted on April 2-11, 1990 following the removal of all of the experiment trays and thermal panels from LDEF. The purpose of this survey was to identify and photodocument features of interest residing on the 6061-T6 aluminum longerons and intercostals which composed the skeletal framework of the LDEF spacecraft.

Prior to initiation of this survey several tests were conducted by Ground Operations- and M&D SIG personnel in an effort to locate a sufficiently stable platform which could accommodate two of the M&D SIG SMISs. To this point in the M&D SIG operations, the majority of photodocumented features had required magnification factors of 25X and 50X in order to produce sufficiently large enough images to assure depth and diameter measurements of ±5%. Utilizing such high magnifications required that an extremely stable platform be used during this on-spacecraft photodocumentation effort to prevent minute vibrations from appearing as large motions within the SMIS; the acquisition and digitization of the desired image took ~1/30th of a second. Attempts to image slightly vibrating objects were unsuccessful and resulted in jittery or out-of-focus images. Imaging tests were performed with an SMIS residing on (1) the scaffolding or platform which was used by Ground Operations personnel for the deintegration of the experiment trays and thermal panels, (2) some mobile scaffolding, and (3) a Bali-more (hydraulic-lift platform on wheels). Each of these tests was unsuccessful; the LATS platform was considered, but did not possess sufficient space to accommodate the necessary equipment. Finally, Ground Operations- and KSC SAEF II personnel located an ~20' x 8' (~6.1 x 2.4 m) flat-bed trailer which was cleaned, brought into SAEF II, and stabilized by floor jacks. Tests which were conducted utilizing this flat-bed trailer revealed that it could be used as a platform as long as all personnel vacated the trailer prior to initiation of the image acquisition procedures (the Bali-more and the Ground Operations deintegration platform were pressed into service to photodocument features on the space- and Earth-end, respectively, as there were no other alternatives). In addition, the test revealed that all other activities within SAEF II had to cease during the M&D SIG photodocumentation of the LDEF frame; walking on the cement floor was often sufficient to induce unacceptable vibrations into the SMIS. Therefore, due to the extreme sensitivity of the SMIS on the flat-bed trailer, the M&D SIG photodocumentation of the LDEF frame was performed between the hours of 5:00 pm and 3:00 am on the above mentioned dates.

As a result of the mismatch in length between the ~30' (9.1 m) long LDEF spacecraft and the ~20' (6.1 m) long flat-bed trailer, the surveying and photodocumentation of the LDEF frame had to be conducted in three phases. During phase one, Bays A-F were completely scanned (on the interior, as well as the spaced-exposed surfaces) and the locations of potential features for microscopic examination and photodocumentation were recorded, while only Bays C-F and part of the Bay B longeron could be photodocumented. Once photodocumentation of all accessible features was completed the flat-bed trailer was unjacked, rolled forward, and rejacked to permit the phase two photodocumentation of the features residing on the frame components of Bay A and the undocumented portion of Bay B. The maximum horizontal extension of the SMIS was ~55"

(~140 cm); at maximum horizontal extension, vertical motion was limited to ~2' (61 cm). As a result of these movement limitations of the SMIS, the spacecraft had to be rotated approximately 15° on LATS in order to completely photodocument an entire bay (the ~4' [~122 cm] horizontal longeron and the ~3' [~91 cm] vertical intercostal) during phases one and two. Phase three consisted of the scanning and photodocumentation of features residing on the structural components of the space- and Earth-ends of LDEF and was carried out with the SMISs on the platforms mentioned above.

Identification of potential features for photodocumentation during the LDEF frame survey followed the same criteria which were discussed previously in detail within Section 2.C.6. In short, features smaller than the M&D SIG threshold value of 0.5 mm in diameter were only photodocumented in the event of some interesting characteristic associated with the feature (*e.g.*, secondaries, debris). Features smaller than the threshold diameter were recorded only with respect to their presence and location, no diameter information or coordinates were recorded. Coordinates for photodocumented features were measured with a metric tape measure from the corner formed by the intersection of the longeron and intercostal associated with a particular bay, the same corner which was located directly behind the experiment-tray flanges where the (0,0) reference point was defined for the associated experiment trays (see Section 2.C.6.a). Because the LDEF frame survey was conducted on the opposite side of the spacecraft from the Ground Operations deintegration platform, the intersection of the longeron and intercostal which defined the (0,0) reference point appeared in the upper right-hand portion of the bay when viewed from the flat-bed trailer. As a result, positive X-values were measured to the left, and positive Y-values down from the (0,0) reference point.

Photodocumented features residing on the longeron of a particular bay were assigned an F01 component number, while photodocumented features on the intercostal were assigned an F02 component number; only Bay F possessed an F03 component as a result of the system adopted by the M&D SIG for naming components of the LDEF frame (see the LDEF Frame summary report in Section 3.C for details on the component names assigned to the various LDEF structural members). Otherwise, the images were similar to those acquired from the various experiment trays in the types of information which was stored with each image (see Section 2.D).

2.C.9 DETAILED THERMAL PANEL SURVEY

The last inspection and photodocumentation effort conducted by the M&D SIG was the Detailed Thermal Panel survey. The initial inspection of this hardware was performed by an M&D SIG member while the remainder of the group was engaged in the efforts related to the LDEF frame survey discussed in Section 2.C.8, above.

The surveying and photodocumentation of these surfaces were carried out on several workbenches with the backside of the space-facing or Earth-facing component of the thermal panel resting on kapton tape which was securing ~20 hexagonal nylon nuts to the workbench surface. The purpose of these nuts was to eliminate contact between the workbench and thermal panel surfaces. The row-facing strip of the thermal panels was allowed to hang over the edge of the workbench and, therefore, did not come into contact with any other material.

Identical threshold values for feature diameters (≥0.5 mm) were utilized during the thermal panel survey as had been used during all previous surveys. The (0,0) reference point was assigned to the lower leftmost corner or angle of each panel (see Figure 26 and the individual summaries of the 24 thermal panels in Section 3.C). Coordinates (for features identified during the initial scan of these surfaces) were measured utilizing one of the CRSs which had been attached to a workbench. The coordinates of additional features which were added during the detailed microscopic examination were measured with a metric tape measure. A positive Z-value was assigned to features residing on the surface of the row-facing strip of each panel, where Z=0 was defined to be the line formed by the intersection of the row-facing strip with the space- or Earth-facing component of the thermal panel. All three SMISs were placed in service for the photodocumentation of the thermal panels (Systems #1 and #2 in horizontal mode and System #3 in vertical mode). Microscopes in their horizontal configuration were utilized to photodocument the space- and Earth-facing components of the various thermal

panels, while System #3 was alternated between Stations #1 and #2 to photodocument the row-facing strips of these panels. Images acquired of features on the thermal panel surfaces contained similar alphanumeric information as had been combined with all previously photodocumented features (see Section 2.D).

The detailed examination of the space- and Earth-end thermal panels at KSC revealed the apparent bimodal distribution of some highly-oblique features; such features were commonly found on the black Earth-end thermal panels, but were apparently absent on their space-facing counterparts. These highly-oblique features were found on both the Earth-facing component and row-facing strip of ~75% of the Earth-end panels. The features initially appeared as little more than streaks or scratches in the black-anodized aluminum of the Earth-end panels, but were determined to be impact-related phenomenon when examined with the SMIS; no apparent dominant directionality was noted for these features. A re-examination of one space-end thermal panel at the Langley Research Center (LaRC) did not reveal the presence of similar features on that particular panel. However, a detailed microscopic scan of several space-end thermal panels is being conducted at LaRC in search of these highly-oblique features.

2.D. IMAGING PROCEDURES

2.D.1. REQUIREMENTS

As a critical part of their operations, the M&D SIG A-Team was required to photodocument all craters on the LDEF spacecraft which were ≥0.5 mm in diameter and all penetration holes through foils or thermal blankets which were ≥0.3 mm in diameter. Furthermore, photodocumentation of these features was required regardless of where they were located. Most photodocumentation was to be performed on the various experiment trays following the removal from LDEF while they were mounted (in the vertical position) on an experiment-tray rotator/stand. Many components, however, as well as some experiment trays, had to be photodocumented in the horizontal position on workbench tops, while still others had to be photodocumented while they were still attached to the LDEF structure (~10' [~3 m] above floor level), hanging from the overhead crane, or resting on the laminar flow bench. In addition, it was necessary to photodocument features of interest as either digitized stereo images for future computer processing, or as 35-mm photographs.

2.D.2. DESCRIPTION OF EQUIPMENT

To meet these specific requirements, the M&D SIG A-Team assembled three Stereo Microscope Imaging Systems (SMIS) from mostly off-the-shelf components. A schematic illustration of the various components composing a complete SMIS can be seen in Figure 29.

Each SMIS consisted of a Wild Leitz M8 stereo-microscope body which possessed four, preset-magnification click-stop positions (6X, 12X, 25X, and 50X), and which could be fitted with one of four objective lenses (350 mm, 0.4X, 1.0X, and 1.6X). Between the top of the M8 body and the 45°-inclined binocular eyepiece tube was a beam splitter which directed 50% of the incoming light to the binocular eyepiece tube and 50% to the camera systems. Attached to both sides of the beam splitter were Cine/TV tubes, on each of which was attached a custom camera adapter; the adapter in turn, could be fitted with an eyepiece. The camera adapters were specially designed to interface with either Nikon F3-HP 35-mm cameras (with MF-14 data backs), or Sony XC-711 CCD video cameras. The custom camera adapter and the binocular eyepiece tubes could be fitted with one of three pairs of eyepieces (10X, 20X, or 32X). Generally, the left binocular tube was fitted with an eyepiece containing a reticle which could be utilized for a quick visual measurement of feature sizes; the reticles were also used for focusing adjustable eyepieces, but were always removed from the camera view prior to imaging.

Illumination for the microscope was provided by a Volpi Intralux 6000 Fiber Optic, Cold-Light Illuminator, from which the light was piped to the imaging/viewing area *via* fiber-optic cables. The light source utilized an Intralux 5000/6000, 20-volt 150-watt tungsten light bulb. One of three fixtures could be attached to the

microscope system to illuminate the object under investigation: (1) a pair of Volpi two-branch flexible "gooseneck" light pipes with focusing lenses (for directional and long-distance lighting), (2) a Volpi ringlight (for 360° uniform lighting), or (3) a Volpi "Hydra" light-pipe system (four directional and distance-adjustable lights held within a ring frame).

STEREO MICROSCOPE IMAGING SYSTEM

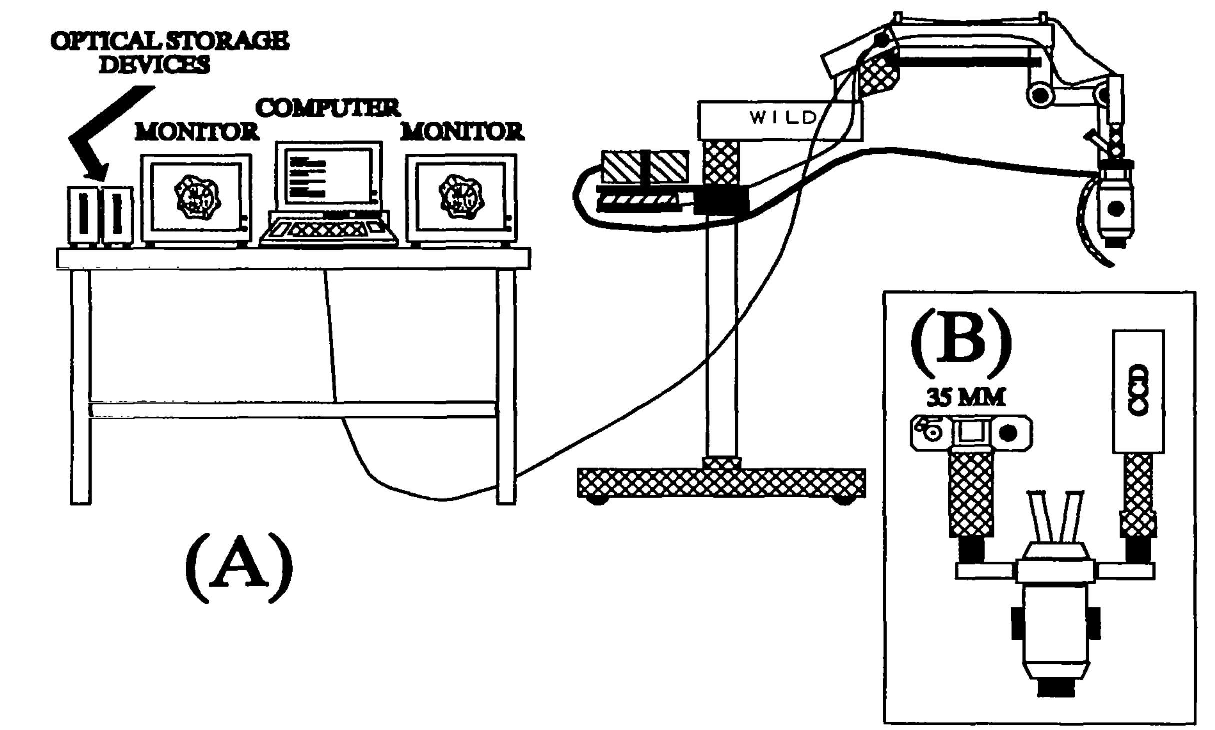


Figure 29. Diagram illustrating the general configuration of the M&D SIG Stereo-Microscope Imaging System. (A) Complete system with computer, two monitors, WORM drives, and microscope on rollable surgical floor-stand and (B) Close-up view of the microscope body with a 35-mm camera attached to the left side and a CCD camera attached to the right side.

The microscope/camera system was attached to a microscope carrier on a fully articulated surgical floor-stand. The floor-stand consisted of a heavy, rolling/lockable base with an ~4' (~1.2 m) tall center post, on top of which was mounted a hydraulic counter-balanced, vertical motion and stability arm (~3' [~0.9 m] long) which could be rotated a full 360° in the horizontal plane at both ends. Attached to the end of the counter-balance arm was an ~1' (30.5 cm) long pin-stopped arm that permitted rotation to six preset positions (15°, 30°, 45°, 90°, 180°, and 270°) in the vertical plane. On the end of this pin-stop arm was another 360° rotation joint, followed by another pin-stopped arm. This final pin-stop arm was attached to the actual microscope carrier, which could be rotated ~235° around the pin-stop arm. Lockheed Engineering and Sciences Company built a small, black-anodized aluminum equipment tray which attached to the top of the center post (under the stability arm) and held the two PS12SU CCD-camera power supplies and the Volpi light source. The integrated system provided complete mobility of the microscope/camera system and permitted the microscope to be moved into virtually any position at heights ranging from ~2.5' to ~7' (~0.8 to ~2.1 m).

Output from the Sony CCD video cameras was carried by standard BNC cables to a computer system for digitization and storage. The computer system consisted of an NEC Portable Powermate 386 SX portable

computer, to which was added a Data Translations DT2871 frame grabber/digitizing board, a Data Translations DT2869 encoder/multiplexer board, two Javelin CVM-13A video monitors, and two Storage Dimensions MAXTOR LS800AT-E External Laser WORM (write once, read many) disk drives. Images were stored on Maxtor 5.25" (13.3 cm) OC-800 optical-disk cartridges (800 megabyte capacity; 400 megabytes per side) which could hold ~495 digitized images on each side. The output signal from the left CCD camera was fed directly into the encoder/multiplexer board which sent the signal to the digitizing board, from where the digitized image was fed back through the encoder/multiplexer board to the left monitor. The signal from the right camera was split, with one line interfacing with the encoder/multiplexer board and the other feeding directly into the right monitor (*i.e.*, the right monitor always displayed a "live" image). The digitized images (left or right) were always displayed on the left monitor.

Two WORM drives were used in order to automatically make an immediate backup copy of all digitized image data. This redundancy ensured there would be no loss of data in case of technical or mechanical failure of components within the systems.

Lockheed Engineering and Sciences Company developed the software used to control the integrated SMIS. The main menu of the software allowed several different choices, including one for recalling stored images, one for changing optical disks, and one for acquiring images. The menu for recalling stored images allowed a stored image to be displayed on the left monitor of the SMIS. This was used primarily to check the quality of images (during periods of hardware problems) and to display interesting features to LDEF Principal Investigators, SIG members, project personnel, and visitors. The menu for changing optical disks was used whenever optical disks had to be changed or flipped, or if the assigned optical-disk number was incorrect. When accessed, the optical-disk software would unlock the disk from the drive unit, permitting replacement or flipping of the storage disk. When disks were flipped, the "read only" switch on the disk was set on the full disk side to prevent accidental data loss. Next, the optical disk number and side were input. After mounting and formatting the disk side (the software would not format a disk on which data already had been written), the software locked the disk and returned to the main menu.

The imaging menu was utilized for all photodocumented features, and permitted the operator to input the LDEF Bay location, component type and number (see below), and experiment number for each imaged feature. The software also interfaced with the digitizer/frame-grabber software (Aurora Library SP0225CN) and WORM drives to provide user-friendly operations through a single, menu-driven package. Based on the LDEF Bay location and the component type, the software would assign a unique number (in ascending order) to each image. The image side (left or right), component type and number, feature number, and LDEF Bay location would then be used to create the file names for the image pair. For example, the right image (R) of an integrated experiment tray's (component E00) third feature (0003) from LDEF Bay D08 would have been given the image file name of "RE000003.D08", while the left image file name for this image pair would have been "LE000003.D08". If multiple images were taken of the same feature, the computer would have assigned the same file name, except that the first letter (identifying the left or right image) would have been changed, starting with "A" for the left and "B" for the right, and would increasing alphabetically with each additional image pair. If a second image pair were acquired for the previous example, the assigned file names would have been "AE000003.D08" and "BE000003.D08" for the left and right images, respectively.

The software also permitted the operator to incorporate the feature coordinates directly from the Coordinate Registration System (CRS; see Section 2.C above), or to input the coordinates manually; the software was limited, however, to accepting X- and Y-coordinate values ≤2000 mm. This limitation only affected measurements for the Earth-end Walking Beam. Finally, the operator was asked to input the magnification (see below) at which the image was being taken and the documentation location (*e.g.*, rotator number, workbench) where the component was located during photodocumentation. The M&D SIG A-Team developed a brief shorthand for the various photodocumentation locations:

Assigned Location Number	Location
0	JSC Rotator
1	LDEF Rotator #1
2	LDEF Rotator #2
3	LDEF Rotator #3
4,5	M&D SIG-Area Workbenches
6	Laminar Flow Bench
9	Integrated LDEF Structure

As a result of the various magnifications which could be utilized by combining the different objectives and eyepieces, the M&D SIG A-Team also generated two tables (combined into Table 1 below) which listed the actual magnification (at the four click-stop positions) of objects as seen by the 35-mm or video cameras. In addition, four images of a stage micrometer were acquired (one at each of the click-stop positions utilizing the 1.0X objective and 10X eyepieces), digitized, and stored in order to provide a calibrated measurement standard.

Table 1. Magnification of images acquired with the M&D SIG Stereo Microscope Imaging System as a function of the (A) objective lens on the microscope, (B) click-stop position of the microscope, and (3) magnification factor of the eyepiece within the video- or 35-mm camera path.

MICROSCOPE		MAGNIFICATION					
	CLICK-STOP	VIDEO			35-MM		
OBJECTIVE	POSITION	10 x	20 x	32 x	10 x	20 x	32 x
0.4	0.6	0.48	0.96	1.54	0.77	1.54	2.46
0.4	1.2	0.96	1.92	3.07	1.54	3.07	4.92
0.4	2.5	2.00	4.00	6.40	3.20	6.40	10.24
0.4	5.0	4.00	8.00	12.80	6.40	12.80	20.48
1.0	0.6	1.20	2.40	3.84	1.92	3.84	6.14
1.0	1.2	2.40	4.80	7.68	3.84	7.68	12.29
1.0	2.5	5.00	10.00	16.00	8.00	16.00	25.60
1.0	5.0	10.00	20.00	32.00	16.00	32.00	51.20
1.6	0.6	1.92	3.84	6.14	3.07	6.14	9.83
1.6	1.2	3.84	7.68	12.29	6.14	12.29	19.66
1.6	2.5	8.00	16.00	25.60	12.80	25.60	40.96
1.6	5.0	16.00	32.00	51.20	25.60	51.20	81.92
350 mm	0.6	0.34	0.67	1.08	0.54	1.08	1.72
350 mm	1.2	0.67	1.34	2.15	1.08	2.15	3.44
350 mm	2.5	1.40	2.80	4.48	2.24	4.48	7.17
350 mm	5.0	2.80	5.60	8.96	4.48	8.96	14.34

Finally, the M&D SIG A-Team developed a shorthand code for the various components of LDEF: E - Experiment Tray; B - Support Beam; C - Experiment-tray clamp; F - Frame (both those attached to experiment trays and the LDEF structural members); G - Grapple; T - Trunnion (including scuff plates); and S - Experiment-tray bolts and shims. The component number "00" was assigned to integrated experiment trays (*i.e.*, component E00 was the integrated experiment tray). As was discussed in an earlier section, the M&D SIG A-Team developed a numbering system for the thermal panels on the Earth- and space-ends of LDEF, and for the clamps, bolts, and shims associated with each experiment tray or thermal panel (see Section 2.C and Figures 18, 19, 20, and 26). For thermal panels, the numbered bolts represent LDEF structural bolts and were not used to attach the thermal panels to LDEF. Instead, holes had been drilled in the thermal panels at the locations of these bolts. The lettered bolts represent those which physically attached the thermal panels to LDEF.

All of this information was added as a single identification line, along with the WORM disk number and side (A or B), at the bottom of the digitized image. This identification line for each image was also included in an "all.img" file. In addition to this identification line, two 65-character comment lines were available for each image. These comment lines were added to the bottom of the image, below the identification line, and were not visible on the monitor. They are resident with the stored image, however, and can be accessed by other monitor types and during post-deintegration image processing. As was the case for the identification line, the comments for each image pair were stored in a separate file called "all.com".

2.D.3. DESCRIPTION OF THE CONFIGURATION USED AT THE KENNEDY SPACE CENTER

At the Kennedy Space Center (KSC), the three M&D SIG photodocumentation systems were configured for deintegration operations in the oven passageway of the Satellite Assembly and Encapsulation Facility #2 (SAEF II). Two SMIS were essentially stationary (Stations #1 and #2) during most of the LDEF deintegration operations, while the third (Station #3) incorporated a rolling/lockable scaffolding bench for the computer and associated hardware to give the entire SMIS mobility. For the two stationary SMIS the computer systems were placed on top of metal tables (~2' x ~7' [~0.6 x ~2.1 m]). Station #1 was located on the left side of the passageway, with Station #2 on the right. The microscope portion of SMIS #1 and #2 was connected to the appropriate computer systems by 20' (~6.1 m) long BNC cables. System #3 utilized a 100' (~30.5 m) long extension cord and 20' (~6.1 m) long BNC cables, allowing full mobility to most sections of SAEF II and access to the entire LDEF Assembly and Transportation System (LATS).

For access to the LDEF structure during the later stages of deintegration operations, the SMIS #2 computer system was placed on an additional rolling/lockable scaffolding bench for mobility. During photodocumentation of the LDEF structure, the microscopes for the two mobile systems were placed on a flatbed trailer (which had been jacked and placed on blocks for stability) to provide the height required to access the LDEF frame components. During these operations, the microscopes and computers were connected by 50' (~152.4 m) long BNC cables.

After the physical setup of all SMIS was completed, the hardware and software components of each were tested. The first optical disks were inserted into the WORM disk drives of each system and mounted *via* the software menu. Since the disks in the two WORM drives systems were to contain identical information, the two disks were assigned the same number. The only difference in the identification number assigned to the two disks was the WORM drive identifier letter (*i.e.* drive "D" or drive "E"). Following the initial checkout, several minor problems with the software were corrected by M&D SIG A-Team personnel at KSC. Once these corrections were made, the revised software was downloaded to the three computer systems, and all three SMIS were ready to begin imaging operations on February 2, 1990.

2.D.4. DESCRIPTION OF OPERATIONS

SMIS imaging operations at KSC began on February 4, 1990, and consisted of two primary modes of operation, horizontal and vertical. The vertical mode was used for imaging experiment trays on the rotators and for documenting the LDEF frame, while the horizontal mode was utilized during photodocumentation of certain experiment trays, bolts, clamps, shims, and other hardware on workbenches. The camera Cine/TV tube attachments had to be rotated 90° (to reduce stress and torques on the tubes, attachments, and cables) when systems were changed between the two modes. During most operations, M&D SIG Systems #1 and #2 were setup in the vertical operating mode, while M&D SIG System #3 was used primarily in the horizontal operating configuration. During the LDEF structural survey, M&D SIG Systems #2 and #3 were used in the vertical operating mode, while M&D SIG System #1 was used in the horizontal operating mode to survey and image the thermal panels and their associated hardware. Changes of SMIS operating orientation of up to ~45° could be accommodated without changing the operating configuration (*e.g.*, from vertical to horizontal mode). All M&D SIG operations were performed in such a manner as to ensure that multiple backups were made of all data collected; all data analysis and result descriptions were reviewed by several members of the M&D SIG. This ensured the maximum collection of data, with minimal possibility for data loss, and prevented reporting of inaccurate data.

2.D.4.a. Alignment Procedures

To ensure that acquired images could be processed later and analyzed to determine the depth and diameter of each imaged feature, microscopes had to be aligned properly. Image analysis and post-processing of a stereo-image pair is possible only after the left and right images are merged to form a 3-dimensional view. In an effort to simplify this registration process, it is necessary to align the left and right images as closely as possible. First, the microscope lens must be parallel to the feature to be imaged. Second, the cameras must be in the same orientation (*i.e.*, up is up), and finally, the displayed images must have the same horizontal and vertical centering. Also, to facilitate imaging, the microscope must be parfocal; that is, the feature much stay in focus as the microscope is switched between magnifications.

In order to facilitate the alignment process, Lockheed Engineering and Sciences Company modified the Cine/TV tubes by adding four allen-head bolts and a shim plate to the side of each tube and to the beam splitter. In addition, to ensure that both images were focused simultaneously regardless of the shim adjustment setting, an adjustable-focus eyepiece was always used in the right camera attachment. This eyepiece was focused outside the microscope, using the reticle, prior to installation in the camera attachment adapter. Once the adjustable eyepiece was properly focused, any further variation in the focus of the two images was generally caused by the microscope not being parallel to the surface being imaged.

The SMIS alignment procedures were relatively simple. Using a sheet of metric graph paper (on which was drawn an arrow for directional alignment of the cameras), the SMIS was first checked (using a metric scale) to ensure that the objective lens was parallel with the graph paper; next, the microscope was focused on the arrow at the lowest magnification. The directional (rotational) alignment was then checked to ensure that both images were correctly displaying the "up" arrow. If not, the camera set screws were loosened, the cameras rotated on the attachment adapters until the alignment was correct, and the set screws re-tightened. Next, the microscope was changed to its highest magnification and refocused. The magnification was then lowered through the other three click-stop positions to ensure that the image stayed in focus. Finally, the images on the monitors were compared for horizontal and vertical alignment. If the horizontal and/or vertical alignment was off by more than 0.5 mm (*i.e.*, half a square on the graph paper), the Cine/TV tubes had to be realigned. It was assumed that the left image was correct, so all horizontal and vertical alignment was performed in a manner which ensured that the right image aligned with the left image. This was done by alternately adjusting pairs of the shim-adjustment bolts on the right Cine/TV tube. Once proper horizontal and vertical alignment were achieved, the alignment procedure was completed.

All three SMIS were aligned during the initial setup at KSC. Subsequently, the alignment was checked at least daily, or every time a SMIS was changed from vertical- to horizontal-operations mode. Actual realignment seldom had to be undertaken during normal operations, but had to be performed each time an operations mode was switched, because the video cameras were kept in a vertical position on the Cine/TV tubes to reduce the stress on cables and the Cine/TV joint. As the microscope was moved between operational modes, the Cine/TV tubes had to be rotated separately to keep the cameras in a vertical position, thus requiring realignment.

To facilitate alignment during the LDEF structural-frame operations, the alignment graph paper was attached to the sides of the two microscopes' swing arms. This allowed the microscopes to be aligned quickly in the vertical mode without requiring the removal of the microscopes from the flatbed trailer.

2.D.4.b. Startup Procedures

Each morning, in order to ensure that consistent numbering of features from one day to the next, the daily "all.img" and "all.com" files were copied from the previous day's post-processed disk to each M&D SIG System's computer hard disk (see Section 2.D.4.e). Each SMIS was then powered and the alignment checked (see Section 2.D.4.a.). In addition, each station was supplied with the appropriate logbook, a metric tape

measure, and metric scale for measuring feature locations and diameters, respectively. The M&D SIG systems were then ready for daily imaging operations.

2.D.4.c. Imaging Procedures

The imaging procedures utilized by the M&D SIG varied slightly between the different scanning locations (*i.e.*, experiment-tray rotators, workbenches, and the LDEF structure). The standard operational configuration for a SMIS utilized the 1.0X objective lens, the 10X eyepieces in the camera paths, the 20X eyepieces in the binocular tube for the operator, and the gooseneck light-pipes. In general, imaging was conducted at the highest magnification which would allow the feature to remain completely within the camera's field of view. In addition, imaging was normally performed by two-person teams, with one individual operating the microscope while the other operated the computer. In addition to increasing efficiency, this provided verification of all information and data collected, ensuring that errors were rapidly spotted and corrected. All M&D SIG members participating in data collection at KSC performed both microscope and computer operations.

2.D.4.c.1 EXPERIMENT-TRAY ROTATOR OPERATIONS

Imaging was performed in three phases for impact features found on experiment trays which were mounted in one of the experiment-tray rotator. The experiment tray was placed in the vertical position, and the SMIS was placed in the vertical operation mode (normally either M&D SIG System #1 or #2). The vertical mode was used for imaging for two primary reasons: (1) it ensured that the SMIS, its related cables, and its operator would not be hanging over the experiment tray, possibly touching or contaminating surfaces, and (2) it permitted the SMIS operator to easily look at the feature through the binocular tube to help discern the three-dimensional nature of the feature. For example, on several occasions it was impossible to tell from the video monitors where the actual crater lip or penetration hole began, or whether a feature had an associated bulge. Looking through the eyepieces gave the operator the visual cues necessary for interpreting the video image and measuring feature diameters. Figure 30 shows two M&D SIG members documenting a feature on the experiment tray from Bay F12 using the 35-mm cameras.

As illustrated in Figure 24, the experiment tray was divided into three zones: high, middle, and low. These divisions were made to allow more efficient imaging of features, since the SMIS orientation had to be changed to allow imaging operations at these different heights. After the survey was completed (as described in Section 2.C. above), the features which had been identified in the upper zone of the experiment tray were imaged first. To configure the SMIS for high-mode operations, the entire SMIS was moved away from the experiment tray to avoid accidental contact. The upper arm of the SMIS was then rotated to an approximately horizontal position, and the microscope body was rotated around its carrier bar to orient it correctly, (*i.e.* "up" in the displayed image was the actual "up" direction). The microscope was checked for vertical orientation using a bubble level and an inclinometer protractor, and the SMIS was moved back to the experiment tray and the goosenecks adjusted to illuminate the feature. This was done by choosing a random position on the upper tray (usually on an experiment-tray flange), focusing the microscope, and positioning the goosenecks to provide proper lighting. The illumination circle of the goosenecks could then be used as a guide for quick location of features and near-focus positioning of the SMIS. The SMIS was then ready for high-zone imaging.

The features identified for high-zone imaging during the survey would then be processed in order. Typically, the imaging began in the upper-left corner of the experiment tray, and started with the features on the experiment-tray flanges and walls. Since the rotators had been marked with "X" and "Y" distances, the coordinates for each feature could be used for quick identification of its general location on the experiment-tray surface. In most cases, when combined with the other survey notes describing the feature, this was enough to identify the feature to be imaged. If the feature could not be positively identified, the CRS was used to duplicate the survey coordinates and positively identify the feature. Once identified, the SMIS was positioned to determine if the feature warranted documentation. This was accomplished by quickly focusing on the feature and making an initial diameter measurement to verify that the feature met the minimum size

Figure 30. Members of the M&D SIG A-Team using one of the Stereo-Microscope Imaging Systems to document an impact feature on the experiment tray from Bay F12. In this picture the imaging system is equipped with 35-mm cameras instead of the CCD cameras.

requirements. The initial focusing was performed most often through the stereo eyepieces, while the final focus was always performed on the monitor to ensure that the digitized left image was in focus. For crater and penetration features, the image was focused approximately half-way down the crater or penetration wall. The M&D SIG standard for measuring feature diameters is to measure the inner-crater diameter at the level of the original target surface; in measuring the diameters at KSC, however, the approximate feature diameters were measured from the monitor screen using a metric scale. Using this technique, attempting to measure the diameter at the level of the original surface would have been a very subjective process. For this reason, the measurements at KSC were made from center-of-rim to center-of-rim on opposing sides of the feature, because these locations were easy to determine, and there was little room for subjective error. The difference in these measurement techniques is illustrated in Figure 31. To ensure that all operators measured approximately the same diameters, measurements were made of a stage micrometer at the four click-stop magnifications in order to generate a set of correlation graphs which permitted screen-measured diameters to be converted to estimated feature diameters (Figure 32).

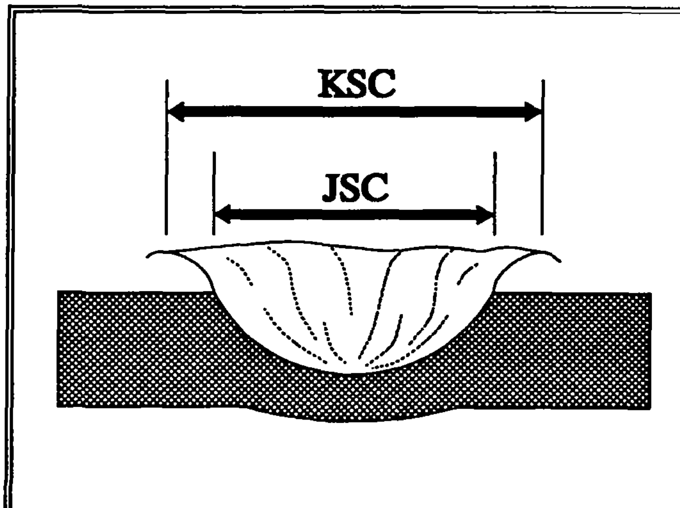


Figure 31. Diagram illustrating the relationship between the estimated (KSC) and the M&D SIG-standard (JSC) diameter measurement techniques. See text.

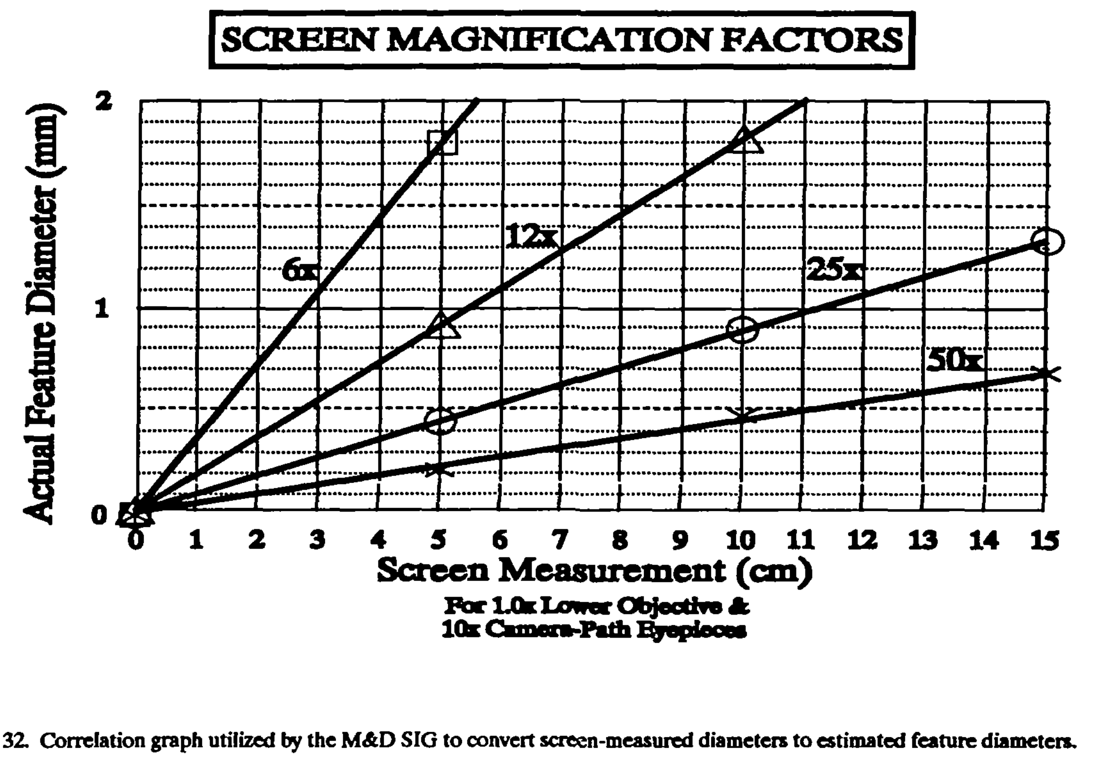


Figure 32. Correlation graph utilized by the M&D SIG to convert screen-measured diameters to estimated feature diameters.

Once the initial focus had been achieved, the computer operator would measure the diameter of the feature on the monitor screen. To convert the screen-measured diameter to the correct estimated diameter, the computer operator would inquire as to the click-stop setting, as well as the objective and eyepiece in use. With this information, the screen-based diameter would then be located on the correlation graph and the appropriate feature diameter interpreted from the graph. When an objective lens was used other than the normal 1.0X (*e.g.*, 1.6X or 0.4X), the appropriate conversion factor was applied to the converted diameter. All feature diameters are estimated to be accurate to within 10%.

In addition to crater and penetration diameters, the diameters of spallation zones, delamination zones, fracture zones, and outer rings were commonly measured. Also, the lengths of cracks and the dimensions of ejecta-spray patterns were often determined. While these were normally measured from the monitor screen, occasionally the dimensions were measured directly from the experiment tray using a metric scale.

Each feature diameter, was noted in the appropriate M&D SIG logbook. If the diameter was smaller than the M&D SIG criteria (≥0.5 mm for craters or ≥0.3 mm for blanket and foil penetrations), the feature was not imaged unless it possessed unique properties (*e.g.*, impact into all unusual material, or a feature with an unusual or interesting morphology). If the feature was not to be imaged, the computer operator would provide the microscope operator with the coordinates of the next feature to be checked. If the feature required imaging, the operator would prepared the computer for imaging.

First, the operator input the coordinates (in millimeters) of the feature being imaged. These could be input manually or could be read (by the computer) directly from the CRS *via* a ribbon cable. The standard method utilized at KSC was to input the coordinates manually. The next entries were the LDEF bay location and the component number (generally, E00) for the experiment tray. The computer utilized these two pieces of information to search the "all.img" file and determine the next available feature number for that bay location and component number. If the image being taken was the second or subsequent image of a particular feature, the operator could manually input the correct feature number and the computer would assign the feature the correct file name (starting with "A" and "B", see Section 2.D.2). Then, for the specific feature to be imaged, the operator would input the experiment number, the magnification, and the appropriate work-stand number on which the experiment tray was located. The feature number was also entered into the logbook next to the feature coordinates, diameter, and brief description. Lastly, the operator could input two comment lines (up to a total of 65 characters each) describing the feature. The standard procedure used by the M&D SIG was to input the feature's approximate diameter(s) and descriptive information about the location or morphology of the feature in the first comment line. The second line would continue the description (if necessary) and end with the type of illumination used during image acquisition (*i.e.*, ringlight [RL] or goosenecks [GN]). Often, other abbreviations were utilized in the comments to ensure sufficient space for adequate feature descriptions. Some typical abbreviations were: DL for delamination, D_1 for the crater diameter, D_2 for the inner spall zone or delamination-zone diameter, and D_3 for the outer spall-zone diameter (in multi-layer spall zones), or for the outer ring or delamination-zone diameter. Occasionally, D_4 and D_5 were used for outer ring and delamination diameters if D_1 through D_3 were already assigned. If an error was made during input, the operator could recycle back through all or portions of the imaging menu to make corrections before saving the image.

Once all data were correct, the image was acquired, digitized, and stored; the entire process typically took about four and one-half minutes. First, the tray location, component number, feature number, and image side (left or right) were combined to form the image-file name as described above. Then the tray location, component number, feature number, experiment number, image-file name, feature coordinates, image magnification, work stand, and optical-disk number and side were combined into the first data line and appended to the bottom of the image. This line of information was also saved to the "all.img" file on the computer's hard disk. Next, the two comment lines were appended to the bottom of the image (these were not displayed on the monitors used at KSC) and stored to the "all.com" file on the computer. The digitized left-image file was then written to a temporary cache location on the hard drive of the computer. Next, the encoder/multiplexing board of the computer would acquire the right image, append the appropriate information to the bottom, and write the digitized image-file to the cache memory. Once all files had been

written to the computer's cache memory, they were transferred to the appropriate WORM optical-disk drives. After this transfer was complete, the software recycled and was ready for the input of the next feature's coordinates. The software retained the previously entered data (work stand, experiment number, tray location, etc.) as defaults for the next image, so the operator only had to input data which changed between features (such as coordinates, magnification, and comments). Any additional comments on the image(s) were also written in the logbooks, to provide multiple backups of the data.

The microscope could not be moved until the right image had been acquired and digitized, or the images would have had to be retaken. Once the right image had been acquired and digitized, the microscope was moved so that the next feature could be measured and prepared for imaging as soon as the computer was ready. The computer was thus the slowest factor in the imaging process.

After all features in the high zone had their diameters checked and were imaged as appropriate, the SMIS would then be reoriented for imaging of the middle zone. Imaging in the middle zone was accomplished as described for the high zone, different only in the physical position of the microscope. The SMIS was moved away from the experiment tray to avoid accidental contact, and the upper arm was rotated down to the near-vertical position. The microscope body would then be rotated on its carrier bar so it was correctly oriented for imaging, (*i.e.* "up" in the displayed image was the actual "up" direction). The microscope was checked for vertical orientation using a bubble level and an inclinometer. The SMIS was moved back to the experiment tray, and the goosenecks were adjusted to illuminate the features. The illumination circle of the goosenecks could then be used as a guide for quick location of features and near-focus positioning of the SMIS. The SMIS was then ready for middle-zone imaging.

When all high- and middle-zone feature imaging had been completed, the SMIS and the rotator stand were prepared for low-zone imaging. Imaging of features in the low zone was accomplished in the same manner as before, but only after both the microscope and the experiment-tray rotator were physically reconfigured to allow ease of operations. Again, the SMIS was moved away from the experiment tray to avoid accidental contact. The rotator stand was then rotated backwards ~35° from vertical, so the low zone of the experiment tray was more accessible. The exact angle was measured with an inclinometer and the microscope was rotated to match the measured angle. This ensured that the microscope was parallel to the features and retained its "up" orientation. The SMIS was moved back to the experiment tray, and the goosenecks were adjusted to illuminate the features. The SMIS was then ready for low-zone imaging.

When features were located on the interior surfaces or on experiment-tray walls, the microscope was rotated, as described above, to allow access to the feature. The M&D SIG attempted to take all images as close to normal to the feature as was possible. Exceptions were noted in the image-file comments and in the logbooks, and are also listed in the various summaries in Section 3.

Throughout the imaging process, if a feature was found which, in the judgment of the M&D SIG, required 35-mm photodocumentation, the feature number was noted in the logbook. After all video imaging was completed on the surface, the SMIS was reconfigured for 35-mm camera operations. The SMIS was moved away from the experiment tray to avoid accidental contact, the BNC and power cables were detached from the video cameras, the set screws on the cameras were loosened, and the video cameras removed from the attachment adapters. The 35-mm cameras were attached to the adapters and oriented such that both cameras were rotationally aligned. The SMIS was moved back to the experiment tray, and the feature illuminated with the light source. Focusing of the object in the camera's viewfinder was accomplished by using the microscope focusing adjustment knob. Once focus was assured, the pictures were taken using cable releases to activate the camera's shutter mechanism. After all 35-mm pictures had been taken, the SMIS was reconfigured for imaging operations with the video camera. The 35-mm cameras were removed and the video cameras re-installed. The SMIS alignment was checked and adjusted if necessary (see Section 2.D.4.a). After all features had been photodocumented, as required, the experiment tray was released by the M&D SIG for other SIG operations prior to thermal-blanket operations, if appropriate.

The operations described here were also used for imaging the thermal panels, with the exception that the Earth- and space-facing component of each thermal panel was documented in the horizontal mode, and the row-facing strip was documented in the vertical configuration.

2.D.4.c.2. WORKBENCH OPERATIONS

Workbench operations were very similar to experiment-tray rotator operations, but were performed with the SMIS in the horizontal operating configuration. Actual imaging procedures were identical to those described above, but the microscope was kept in the horizontal mode at all times. It was tilted only for impact features on experiment-tray walls or angled experimental surfaces. When experiment trays were imaged on the workbench (primarily the S0001 experiment trays), the binocular eyepieces were rarely used prevent the microscope operator from having to lean over the tray and possibly contaminating or touching a surface.

The SMIS was used in horizontal mode both for surveying and imaging of features on experiment-tray clamps, bolts, and shims, as well as on other materials removed from various experiment tray (such as foils), . When used for clamps, bolts, shims, and removed experiment-tray materials, the SMIS was operated by a single individual who performed both the microscope and computer operations.

2.D.4.c.3. LDEF STRUCTURAL-FRAME OPERATIONS

As a result of the large number and amplitude of vibrations generated within SAEF II during daytime deintegration operations, all LDEF structural-frame imaging operations were conducted at night. As described earlier in Section 2.C.8, the LDEF structural frame was imaged by placing the M&D SIG System #2 and #3 microscopes on a flatbed trailer (which had been moved into SAEF II, jacked, and blocked) to minimize vibrations. Thick aluminum plates were placed on the bed of the trailer nearest LATS to facilitate easy movement of the microscope's floor-stands. After the survey for features of interest was completed, the microscopes were aligned, rolled next to LATS, and prepared for imaging. The flatbed trailer was only long enough to allow imaging of five of the six bays of the LDEF structure. Initially, the trailer was setup to allow imaging of Bays B through F; after these bays were completed, it was moved forward to allow imaging of Bay A.

Surveying and imaging of the LDEF frame began with Row 5. System #2 was used for imaging Bays A through C, and System #3 for imaging Bays D through F. LDEF had to be rotated to bring the various frame components to a level accessible to the SMIS. The microscopes were positioned such that the objective lens was parallel with the frame component being examined. During all LDEF structural-frame operations, the microscope operator would locate features and focus the microscope while standing on LATS. Generally, all features on the longeron of a particular row were imaged first, as described above. Once completed, the microscopes were rotated to the same angle as the upper portions of the intercostals on that row (which were at $\sim 15^{o}$ to the longerons), and the features found on the intercostal within the SMIS' reach were imaged. LDEF was then rotated so the lower portion of the intercostal could be imaged. Again, the microscopes were rotated to be parallel with the lower portions of the intercostals; once accomplished, the rest of the intercostal features were imaged. LDEF was again rotated to bring the next longeron into position, the microscopes were repositioned to be parallel, and surveying and imaging of the next row began.

In order to image features on the space-facing end of LDEF, System #3 was placed on the Bali-more lift, which was positioned at the end of LATS. LDEF was rotated to bring each longeron and intercostal into range of the SMIS; the microscope operator stood on LATS to locate features and focus the microscope. This minimized the vibrations introduced into the Bali-more lift. Imaging of features on the Earth-facing end of LDEF was accomplished with System #2, which was placed on the deintegration scaffolding. As before, the microscope operator stood on LATS to locate features and to focus the microscope.

Throughout the imaging process, both microscopes had to be completely focused and ready prior to initiating the image-acquisition procedures on both systems, which was always done simultaneously, because the

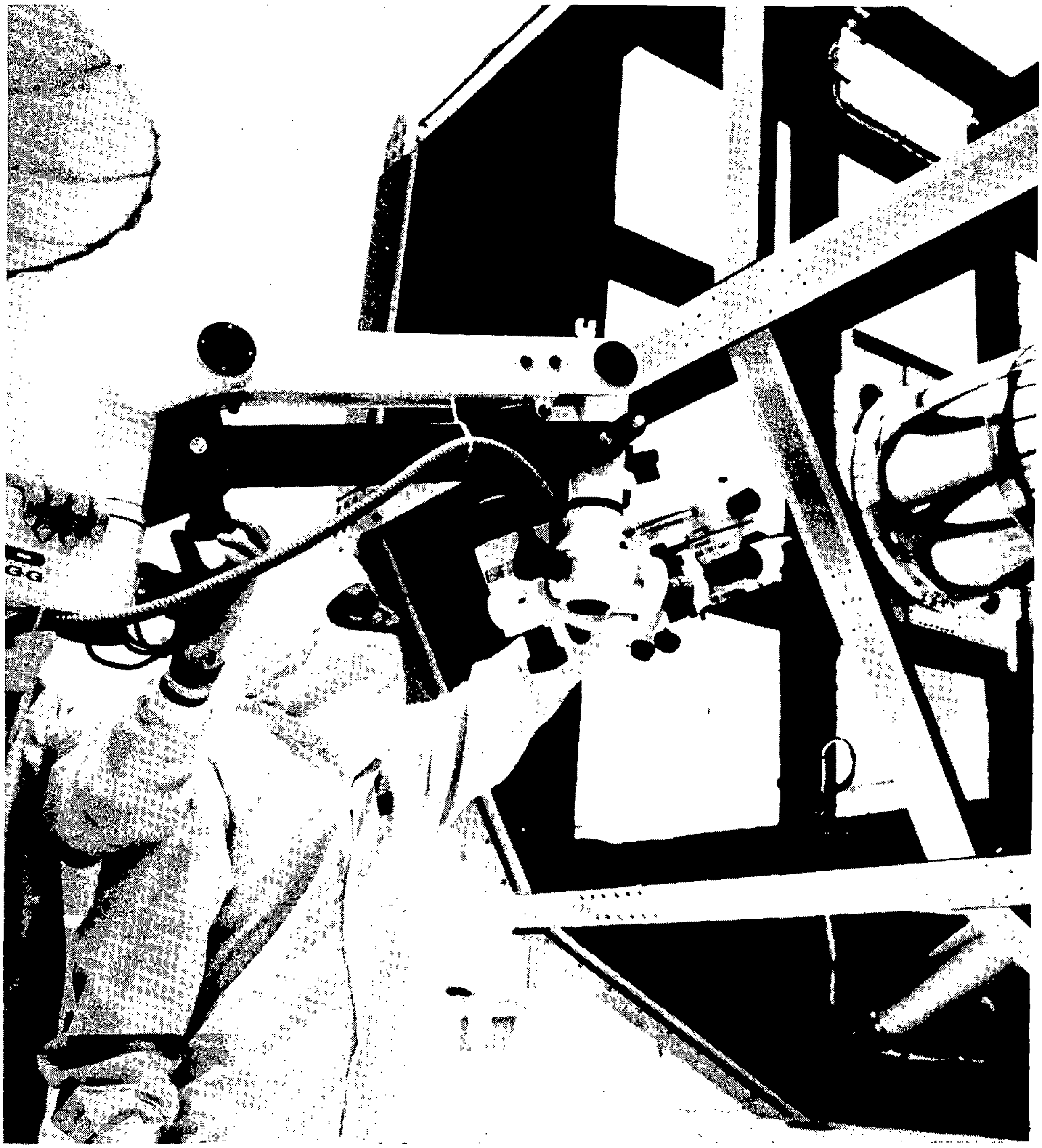


Figure 33. Members of the M&D SIG A-Team shown configuring one of the Stereo-Microscope Imaging Systems for photodocumentation of the LDEF structural frame. Note the dark discoloration of the space-exposed areas on the structural-frame members.

movement and focusing of the SMIS caused vibrations. In addition, the microscope operators had to get off LATS and the flatbed trailer prior to imaging, as any motion generated vibrations which disturbed the imaging process.

During the imaging of the LDEF frame, certain computer hardware began to fail (*i.e.*, when the computer tried to "grab" and digitize the right image, the image was not synchronized and was unusable). This problem required that multiple images of individual features had to be taken in order to acquire one usable image pair. The problem was eventually traced to overheating of the digitizing boards. The source of the problem, however, was not determined until after the imaging of the LDEF frame had been completed, and the faulty boards were not repaired until after the KSC operations had been completed.

2.D.4.c.4 PROCEDURE DOCUMENTATION

While at KSC, the M&D SIG operations were documented on video tape using a Panasonic Omnivision Camcorder mounted on a tripod. Two hour video-tape recordings were made of the primary M&D SIG operations in order to provide visual documentation of the procedures used by this group during LDEF deintegration. During the three month stay of the M&D SIG at KSC, a total of 20 video tapes were made of various M&D SIG operations. These video tapes are archived at in the Curatorial Facility at JSC.

In addition, the M&D SIG utilized a Nikon F3-HP 35-mm camera (with an MF-14 data back) as a hand-held or tripod-mounted documentation source. The camera was fitted with either a 55-mm macro lens or a 70-110 mm macro-zoom lens to photograph important impact features and M&D SIG-related events. This was also the camera used to photograph the thermal blankets following trisection and deintegration from the various experiment trays.

2.D.4.d. Shut-down Procedures

At the end of each day of operations, the SMIS were shut-down and stored to prevent damage. The SMIS were moved into the M&D SIG area, all power was turned off, and all BNC cables and extension cords were unplugged and rolled up. The pens, logbooks, and metric scales were put into the M&D SIG tool boxes for the night, and the camcorder was placed into its storage case. All 35-mm cameras -- the hand-held camera in particular -- were placed in the storage cabinet in the M&D SIG area, as was all miscellaneous hardware (such as Kapton tape, scalpels, and velcro).

Prior to powering down the computers, the daily "all.img" and "all.com" files were downloaded to 3-1/2" floppy disks for processing. Prior to copying to the floppy disk, each file was copied to another file, using the date, M&D SIG system number, and the ".com" or ".img" designator as appropriate in the construction of the new file name. For example, the image ("all.img") and comment ("all.com") files taken using M&D SIG System #2 on March 12 was named "03-12-S2.img" and "03-12-S2.com", respectively. These files were then copied to two floppy disks to provide backups. Once all three systems had been downloaded in this manner, the computers were turned off.

Finally, if any experiment trays were to remain in the M&D SIG area overnight, Ground Operations Personnel would install the experiment-tray covers to minimize potential damage to experimental surfaces.

2.D.4.e. Daily File-Processing Procedures

After shutdown of all equipment, one of the floppy disks with the daily downloaded files was taken out of SAEF II for processing. The files on this disk were copied to a Bernoulli disk and also onto an internal hard disk for processing operations. Each image file was loaded, and the highest feature number from each experiment tray was copied into a "master.img" file. When completed for all three image files, the "master.img" file was copied into the "all.img" file for uploading into the three computers during the next morning's startup operations. In addition to the "all.img" file, a blank "all.com" file was created on the floppy disk for uploading to the computers during the startup operations.

This post-processing of the "all.img" file was necessary to ensure that all three systems started each day with the same feature numbers for all trays. If this had not been done, duplicate or incorrect file names and feature numbers could have been assigned to features imaged on an experiment tray by a different SMIS at some later time. Unfortunately, this did happened on at least one occasion, but it was noted in the logbook for future reference. Identical file names and feature numbers for different feature, or different file names and features numbers for the same feature would have made the image processing and statistical analysis at JSC extremely difficult.

The conclusion of these daily processing operations ended the daily M&D SIG operations at KSC. The post-processing operations also guaranteed an additional backup of all data, outside of SAEF II, and provided the M&D SIG with the opportunity, occasionally used, to print out the "all.img" and "all.com" files, if required.

2.E. THERMAL BLANKET PROCESSING

2.E.1. BACKGROUND

Through negotiations conducted before the retrieval of LDEF, the M&D SIG was able to obtain access to all 17 of the Scheldahl G411500 thermal blankets on the spacecraft. From the M&D SIG point-of-view, it was very desirable to obtain these thermal blankets because they provided a large, uniform meteoroid detection surface randomly spaced around LDEF; only Rows 3, 9, and 12 did not contain an A0178 experiment tray. The blankets were flown to provide thermal insulation to the Ultra-Heavy Cosmic-Ray Nuclei Experiment [A0178, 16 blankets] and the SEEDS Experiments [P0004/P0006, one blanket]. As part of the negotiated agreement, the M&D SIG was responsible for trisecting, removing, and packaging all thermal blankets. According to the agreement, the left 1/3 of each A0178 blanket was to be archived at the Johnson Space Center (JSC), while the other 2/3 were to be shipped to the European Space Technology Center (ESTEC) in The Netherlands. The entire P0004/P0006 blanket was to be archived at JSC. Extensive work went into the construction of specialized packaging containers for non-destructive shipping of the blanket sections to their international archive locations. The text below describes the trisection, removal, and packaging procedures of the thermal blankets at the Kennedy Space Center (KSC) after the experimental trays had been removed from LDEF.

2.E.2. THERMAL BLANKET DESCRIPTION

The A0178 and P0004/P0006 experiments were thermally insulated from the space environment by ~200 μm thick thermal blankets which were mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (space facing) of FEP Teflon (~120 μm thick) backed by a thin layer of vapor-deposited silver/inconel (~200 to 300 Å thick), which in turn was backed by DC1200 primer and Chemglaze Z306 black conductive paint (~80 to 100 μm thick). Each of the A0178 experiment trays included a 40-5052 aluminum support frame (designed to support the thermal blanket), which consisted of four horizontal and four vertical aluminum channels mounted just below the level of

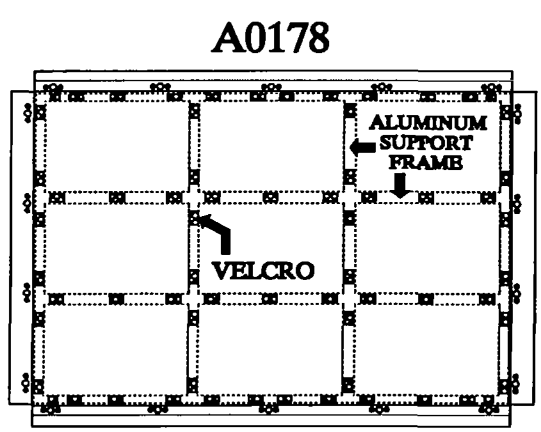


Figure 34. Diagram of an A0178 experiment tray following the removal of the thermal blanket, illustrating the locations of the velcro strips on the underlying aluminum support frame.

the experiment-tray flanges. This, and was designed to support the thermal blanket. Each thermal blanket was attached to the experiment tray by ~64 strips of ~1" x 2" long (2.5 x 5.1 cm) velcro located before and after each horizontal and vertical junction of the aluminum support frame (Figure 34). An enclosed area around the experimental canisters was formed by an ~1" (2.5 cm) piece of unexposed thermal blanket which was folded between the experiment-tray wall and the experimental canisters (see NASA Photographs KSC-390C-1028.12, KSC-390C-1029.01, and KSC-390C-1029.10). Each blanket was electrically grounded by an ~1" x 8" (2.5 x 20.3 cm) copper grounding strap which was attached to the lower, middle backside of each thermal blanket. The other end of the grounding strap was attached to the LDEF structural frame by two of the bolts on the center bottom experiment-tray clamp (C06).

2.E.3. CONSTRUCTION OF THERMAL BLANKET BOXES

Prior to the retrieval of LDEF, personnel at JSC designed and constructed thermal blanket boxes (TBB) for the purposes of protecting and transporting the trisected thermal blankets from the Satellite Assembly and Encapsulation Facility (SAEF II) at KSC to JSC and ESTEC. The frame of each TBB was constructed from 0.125" (3.2 mm) thick, 6061-T6 aluminum channel (chromic anodized for clean operations) which were welded to form a rectangular box with inner dimensions of 40" x 21.6" x 3" (101.6 x 54.9 x 7.6 cm). This volume provided sufficient room to suspend the blanket inside the box while preventing contact between the blanket and any part of the container. The top and bottom of each container were constructed from 0.125" (3.2 mm) thick lexan sheets, and secured to the aluminum frame by 16 stainless-steel screws. The transparent top and bottom of the TBB provided contamination protection, while still permitting limited optical scanning of the enclosed thermal blankets. To allow attachment of the thermal blanket, the inside of the TBB contained an adjustable standoff frame of aluminum angle, 1.25" x 1.25" x 0.125" (3.1 x 3.1 x 0.32 cm) on a side, and an identical aluminum angle 1.25" x 0.125" (3.1 x 0.32 cm) which was welded to the opposite side of the inner wall of the TBB. The adjustable aluminum angle was designed to provide sufficient tension on the blanket to prevent its sagging while in the TBB. The adjustable angle was held in place by threaded nylon rods and nuts (Figure 35) which were centered between the lexan sheets by lexan standoffs which attached the lexan bottom using adhesive-backed velcro. Following its assembly, each TBB was cleaned, packaged in a vacuum-sealed polyethylene bag, and placed into a specially designed wooden crates for shipment to KSC.

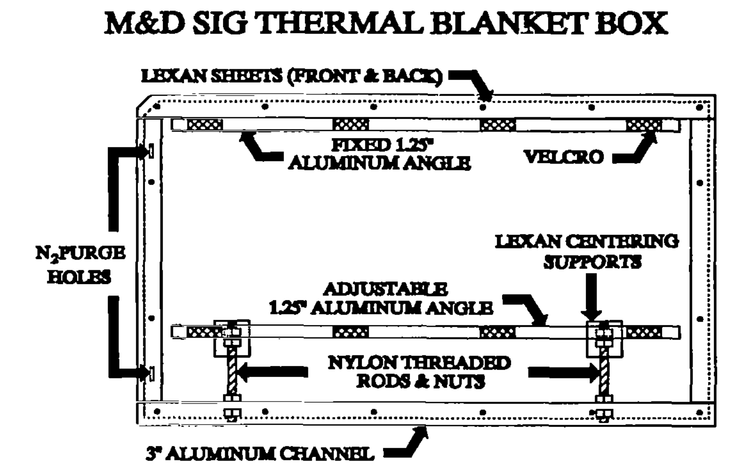


Figure 35. Diagram of an M&D SIG Thermal Blanket Box used to transport the trisected thermal blankets to JSC and ESTEC. These boxes were also used to ship other miscellaneous hardware items from KSC to JSC.

2.E.4. THERMAL BLANKET PACKAGING PROCEDURES

The thermal blanket packaging procedure consisted of six steps: (1) Thermal Blanket Box (TBB) preparation, (2) survey and preparation of the thermal blanket, (3) trisection of the blanket, (4) blanket removal and placement into the TBB, (5) thermal blanket photography, and (6) final sealing and shipping. These procedures were followed for the removal of all A0178 and P0004/P0006 thermal blankets from their experiment trays.

2.E.4.a. Preparation of Thermal Blanket Boxes

The empty TBBs were delivered to KSC within vacuum-sealed polyethylene bags prepared for clean-room operations. As the boxes were removed from the polyethylene bags, the M&D SIG A-Team noticed that the screws holding the lexan top and bottom onto the frame were causing small puncture holes in the polyethylene bags. To correct this problem, the boxes were removed from the bags, placed top-side down on a small workbench, and small ~1" x 1" (~2.5 x 2.5 cm) pieces of Kapton tape were placed over the heads of the screws on the bottom of each box. The box was then flipped, and the top piece of the lexan removed to prepare the adjustable aluminum angle for thermal blanket attachment. Threaded nylon rods were cut to ~14.5" (~36.8 cm) long pieces and inserted through the holes in the aluminum frame, the holes of the lexan standoffs, and the holes in the adjustable aluminum angle. The aluminum angle was attached to the nylon rods with nylon nuts and washers, and were then securely positioned in the TBB (Figure 35).

2.E.4.b. Survey and Preparation Of The Thermal Blankets

After the TBBs were configured, the blankets were prepared for packaging. First, the ~1" (2.5 cm) piece of the thermal blanket which was folded between the experiment-tray wall and the experiment canisters was unfolded to expose the entire surface area of the blanket. This was accomplished by releasing the edge with the blunt end of a scalpel and then running a gloved finger around all four sides of the tray to release the rest of the covered area. When fully unfolded, the unexposed blanket rested on top of the experiment-tray flanges. The blanket was then inspected by a member of the M&D SIG A-Team to determine the best places to trisect the blanket: as a result of the random distribution of impact features on the thermal-blanket surfaces, the actual cutting operations were performed in such a manner as to avoid cutting through penetration features or their associated delamination zones whenever possible (see Figure C11-1 in Section 3.B). In order to accomplish this, a pre-trisection survey was conducted to locate features which might be affected, and to "map out" the planned trisection path.

2.E.4.c. Trisection Of The Thermal Blanket

The outline of the velcro strips, attaching the blanket to the aluminum support frames of the experiment tray were used as a cutting guide in the trisection of each thermal blanket (see Figure A10-1 in Section 3.B). An incision was made through the middle of the velcro strips in order to have velcro on both sides of the trisected piece of blanket to facilitate attachment inside the TBB. Starting ~1" (~2.5 cm) below the top the of the thermal blanket, a scalpel blade was used to make the initial incision in line with the first vertical row of velcro strips. The incision was extended slowly through the velcro strips and the thermal blanket until the bottom of the blanket was reached. When an impact feature was in the path of the incision, it was skirted to preserve the feature and associated delamination zones, if present. Extreme care was taken while trisecting the thermal blanket to assure that, when a piece of velcro was cut through, the scalpel did not "jump" and slice the blanket in an undesirable manner. With the scalpel blade turned upside down, the remaining top ~1" (2.5 cm) section of blanket was cut. While cutting the thermal blankets the M&D SIG A-Team observed that the blankets from the leading edge of LDEF tended to be thinner and easier to cut (including the velcro) than their trailing-edge counterparts. The entire blanket remained on the experiment tray while the second incision was made on the second vertical row of velcro strips to complete the trisection procedures.

Grounding straps from 11 of the A0178 experiments (A02, A04, A10, B05, B07, C05, C08, C11, D05, D11, and F04) were committed to the Materials SIG. Since the tension of the blanket on the experiment tray was greater than when it was in the TBB making the thermal blanket much easier to cut, the grounding strap was removed from each thermal blanket while the blanket was still attached to the experiment tray. The grounding strap was detached by cutting an ~4" (~10.2 cm) diameter semi-circle around the point where the strap was attached to the thermal blanket. Again, any impacts were avoided so as to preserve them intact with their associated delamination zones. (A photograph of the thermal blanket with the grounding strap removed is shown in NASA Photographs S90-43525 and S90-43526). Once freed, the grounding strap was removed with a small pair of forceps, placed in a clean plastic container, marked orient it with respect to on LDEF, and

given to the Materials SIG. If impact features were located on the semi-circular area which was removed from the thermal blanket, the number and location of each impact was noted in the logbook.

2.E.4.d. Blanket Removal And Placement In The Thermal Blanket Box

Following trisection, the left third of the thermal blanket was removed from the experiment. With two people securing the upper corners of the blanket, the velcro on the back of the blanket was slowly separated from the velcro attached to the aluminum support frame, releasing the blanket from the experiment tray (Figure 36). While one person held the detached thermal blanket by the upper corners, another would cut pieces of adhesive-backed velcro matching the size to the velcro which remained on the back of the thermal blanket. The pieces of velcro were secured carefully to the piece on the back of the blanket. Before the thermal blanket was placed in the TBB, the top and bottom widths of the blanket were measured in order to establish the correct location for the adjustable aluminum angle. Two people held the upper and lower right-hand corners of the thermal blanket while the cover-strips of the adhesive backing of the velcro were removed. As one person held the blanket at an ~45° angle away from the TBB, the other would slowly and carefully press the velcro onto the 1.25" thick (3.2 cm) aluminum angle in the TBB. This process was repeated until the entire right side of the thermal blanket was attached to the stationary aluminum angle. The left side of the thermal blanket was attached to the adjustable aluminum angle in a similar manner. After the blanket was secured to both sides of the TBB, tension was applied to the blanket by adjusting the position of aluminum frame back along the nylon rods and tightening the nylon nuts on either side of the TBB channel. The adhesive backing the cover strips of velcro, attached to the bottom of the lexan standoffs was removed, and the lexan standoffs were pressed down to secure them to the bottom lexan piece of the TBB. This insured no movement of the standoff frame or blanket inside the TBB during shipment.

From every U.S. (JSC) portion of the thermal blankets, the M&D SIG was required to remove, from either end of the blanket, an ~4" (10.2 cm) wide strip to be given to the Materials SIG. Extreme care was taken to determine which end would be cut in order to lose the fewest impact features. Prior to removal, each area on either end of the thermal blanket was inspected, and all impact features counted in the 4" wide area. The decision of which end to cut was based on two factors: (1) the number of impact features which would be lost and (2) individual features of great interest with large or unusual delamination zones. The number of impacts lost per 4" wide strip was recorded in the logbook. (A photograph of a thermal blanket with a 4" strip removed is shown in NASA Photographs S90-43523 and S90-43524).

After the Materials SIG portion of the thermal blanket was removed, the lexan top was secured into position with 16 stainless-steel screws and the ~1" x 1" (2.5 x 2.5 cm) pieces of Kapton tape were placed over each of the screw heads to prevent them from puncturing the polyethylene bags. The bay location, experiment number, blanket orientation, and specified one third was written in the lower right-hand corner of the top of each lexan box. This process, except for the removal of the Materials SIG portion, was repeated for each of the remaining two thirds of the thermal blanket.

2.E.4.e. Thermal Blanket Photography

Prior to final packaging and shipping, photographs were taken for documentation purposes of the blankets secured within the TBB's. The M&D SIG also wanted photographs of the thermal blankets with various pieces removed (*e.g.*, the 4" wide strip), again for documentation purposes. The workbench on which all thermal blanket processing took place was located in front of the emergency exit of the oven passageway in SAEF II. This exit contained a small rectangular window which allowed excessive light into the oven passageway and, unfortunately, onto the TBBs during photography. To reduce the glare from the window during thermal blanket photography, a piece of thin metal was held over the window by a member of the M&D SIG.

The TBB was placed on its side and situated near the edge of the workbench so that the thermal blanket was "hanging" with in the box. A 35mm Nikon camera (F3-HP with an M4-14 data back) was set up on a tripod

Figure 36. Photograph showing the removal of the thermal blanket from the SEEDS in Space Experiment (P0004/P0006).

located ~2 m directly in front of the TBB. The camera was focused in such a way so as to primarily fill the frame of the picture with the TBB. Early in the thermal blanket processing a total of three photographs were taken: (1) a front view directly in front of the TBB, (2) a front view at a slight angle to the TBB, and (3) a back view of the thermal blanket with back-lighting. Some of the initial rolls of film were developed at KSC, following which the M&D SIG A-Team deemed it useless to take the direct front- view photograph of the thermal blankets because of the reflection from the camera's flash caused by the lexan top and the metallic shining thermal blanket surface. The back views were taken with a photographers' lamp, providing backlighting to the TBB to transmit light through the penetration holes in the thermal blanket. In this way the M&D SIG A-Team could determine how many impact features actually penetrated the blanket. In order to illuminate only the thermal blanket area, two large plastic container tops were held up against the back of the TBB covering only the area where the thermal blanket did not hang (see Figure A10-1 in Section 3.B). In these photographs, the penetrations appear as bright illuminated spots on the black-painted backside of the thermal blanket. With backlighting, the penetrations became apparent and were easily counted by members of the M&D SIG A-Team. No flash was used on the photographs of the backside, so an extended exposure was necessary to compensate for low light-levels. After the photographs were taken, a member of the M&D SIG counted all penetrations through the blanket using the backlighting and entered the results in a personal logbook.

The interior of the experiment tray was then surveyed to identify possible blanket-penetration ejecta patterns. When encountered, these features were imaged as described above in Section 2.D.

2.E.4.f. Final Packaging And Shipping

The final steps for the thermal blanket processing involved final packaging and sealing. The TBB, with the thermal blanket secured inside, was placed horizontally in a pre-cleaned polyethylene bag and heat sealed, leaving only a small opening to push a dry-nitrogen hose into the bag. A dry-nitrogen flush of the TBB was then performed for approximately two minutes through a small 0.25" (6.3 mm) purge hole in the side of one of the aluminum channels (see Figure 35). Following the nitrogen purge, a vacuum was pulled on the polyethylene bag and the bag was heat-sealed closed. The TBB was placed into a second pre-cleaned polyethylene bag and vacuum sealed, preparing the TBB and its contents for shipment. The encapsulated TBB was inserted vertically (standing on edge with the adjustable angle down so the thermal blanket was "hanging") into a specially designed (foam lined) wooden shipping crate. The boxes were inserted, five to each crate, between ~4" (10.2 cm) pieces of foam rubber to prevent the boxes from moving inside the wooden crates. A final piece of foam was placed at the end of the crate and the top was screwed shut. The crates were then labeled with, "FRAGILE", "CRITICAL SPACE ITEM, HANDLE WITH CARE", and "THIS END UP" stickers, and marked for shipment to either JSC or ESTEC.

SECTION 3

TRAY AND HARDWARE SUMMARIES

3.A GENERAL SUMMARY

The LDEF spacecraft was a 14-faced (12 sides and two ends), open-grid structure on which a series of rectangular trays used for mounting experiment hardware were attached. Bays A01-F12 held the larger, rectangular, peripheral experiment trays that housed 72 of the 86 experiments, while the remaining 14 experiments resided within square-shaped experiment trays on either the space-facing (eight bays) or Earth-facing ends (six bays) of the spacecraft. The larger peripheral trays possessed dimensions of ~34" x 50" (~86.4 x 127 cm), while the space-facing and Earth-facing end trays measured ~34 in^2 (86.4 cm^2); three depths (*i.e.*, 3" [7.62 cm], 6" [15.24 cm], and 12" [30.48 cm]) of experiment trays were available. All experiment trays were constructed of chromic-anodized 6061-T6 aluminum with the 6"- and 12"-deep trays utilizing 0.125" (3.175 mm) thick aluminum, and the 3"-deep variety utilizing 0.0625" (1.5875 mm) thick aluminum. A series of alphanumeric identifiers (*i.e.*, a hardware code) was stamped into the bottom flange of each experiment tray; six and 12"-deep trays possessed this code on the right side of the flange, while 3"-deep trays had the code stamped into the left side of the bottom flange. The typical experiment weight that could be accommodated by the experiment trays was ~180 to 200 lbs (~396 to 440 kilos) for the peripheral and end trays, respectively.

All experiment trays were held within their respective bays by 1.9" x 5" x 0.18" (4.8 x 12.7 x 4.5 cm) thick, 6061-T6 chromic-anodized aluminum clamps; each clamp was fastened to the spacecraft by three hex-head, 303 stainless steel bolts. Peripheral experiment trays utilized eight clamps to hold the tray in place, while end trays were affixed to the spacecraft by 12 clamps (see Section 2.C, Figure 19).

A wide variety of impact-feature morphologies were encountered on numerous experiment trays and material types flown on LDEF. A detailed description of impact-feature morphologies can be found in Section 2.B.

The M&D SIG survey of the entire LDEF spacecraft identified a total of ~34000 features on all space-exposed surfaces, including three features which were located on interior portions of structural-frame members. The values listed below in the Feature Summary Table do not represent a complete count of the number of impacts on LDEF. The reasons for this are as follows: (1) of the thousands of suspected features which were examined microscopically, a small percentage were determined to have resulted from causes other than impact (*e.g.*, tears in thin materials, scratches or dents in metallic surfaces, etc..). An equal or greater percentage of the tens of thousands of impact features categorized as "Too Small", which were not examined microscopically, probably had similar origins. (2) Many surfaces were examined where the locations of the "Too Smalls" were not recorded (*e.g.*, between the experiment-tray flanges and experimental surfaces). (3) During the first several days of the KSC operations by the M&D SIG, only those features which were photodocumented were counted.

Keeping this in mind, the number of impacts in the three categories listed below represents only those impacts *known* to exist on each of the surface types. There are discrepancies in the table below, in that the actual sums along the "<0.3 mm" and "<0.5 mm" rows are smaller than the respected figures given in the "Totals" column. This disagreement is due to reason (2) above. The "Clamps, Bolts, And Shims" column includes all experiment-tray clamps, bolts, and shims as well as all thermal-panel bolts and reflectors. The "Tray-Flange" column includes only the experiment-tray flanges. Conversely, the "Experiment Surfaces" column includes all PI experimental surfaces, thermal panels, scuff plates, walking beam, and the LDEF structural frame.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			2911	3069
>0.3 mm			763	763
<0.5 mm	1318	1923	19342	27385
>0.5 mm	161	419	2539	3119
TOTALS	1479	2342	25555	34336

The largest impact features identified on the entire spacecraft was an ~5.25 mm in diameter crater which was located on a ram-facing Z-frame of the A0038 experiment.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection of all 86 experiment trays was conducted on February 20-23, 1990 while the experiment trays were mounted on the spacecraft. During this inspection, if features were located in the experiment-tray cover area, an effort to protect the more interesting features was made by cutting the cover gaskets in these locations. The purpose of removing the gasket material was to prevent the gasket from contacting and contaminating these features, and to provide a stand-off distance between the experiment-tray cover and the experiment-tray flanges. When features were found on bolts or on clamps near bolts, a request was made for the use of special tools (*i.e.*, open-end wrench) or handling procedures during the actual deintegration of the various experiment trays.

A detailed description of the on-spacecraft inspection by the M&D SIG can be found in Section 2.C.4.

GENERAL FRONT AND BACKSIDE:

M&D SIG members performed a general front- and backside survey of every experiment tray subsequent to its removal from the spacecraft, and prior to its installation within one of the six rotators. The inspection was performed by first looking at the backside of the experiment-tray flanges for phenomenon related to front-surface impacts (*e.g.*, bulges, spallation effects, penetration and ejecta effects) which could be damaged or altered by the experiment-tray stand clamping mechanism. Next, the back surface of the experiment tray was examined for anything unusual (*e.g.*, back-surface impacts, outgassing stains, discoloration, etc.). Following the completion of this inspection the findings were entered in the *Summary Books* kept by the M&D SIG A-Team throughout their KSC operations.

DOCUMENTATION:

Examination and photodocumentation of all 86 experiment trays and related hardware was conducted from February 23 through April 19, 1990. The majority of experiment trays were examined in the vertical position utilizing Coordinate Registration Systems (CRS) #1, #2, and #3 to determine the feature's location, and M&D SIG Systems #1 and #2 to acquire and store the various digitized stereo-image pairs. Unless requested not to do so by the experiment PI, a small black or red dot of indelible ink was placed on the lower part of the left experiment-tray flange to act as a (0,0) reference point for feature coordinate registration (see Section 2.C.6.a for a detailed description of the standards adopted by the M&D SIG for the assignment of the (0,0) reference point). Many trays were indexed by recording the locations of small machined holes positioned to the left of the top and bottom, left, center, and right experiment-tray cover bolt holes (see Figure 28). In addition, six fiducial marks were placed on the A0178 thermal blankets with black or red indelible ink and their position determined and recorded (see examples below).

Experiments which arrived in the M&D SIG area in one of the JSC rotators could not utilize an electronic CRS due to the rotator's tubular-frame construction not permitting the CRS to interface properly with these units. In such events, the coordinates were determined by means of a metric tape measure, with the X- and Y-distances being measured from the same (0,0) reference point which would have been utilized with the CRS.

The majority of the Space Debris Impact Experiments (S0001) were examined in the horizontal position, generally utilizing M&D SIG System #3; a few of these trays were photodocumented with one of the other two M&D SIG Systems. Coordinates for the photodocumented features on these trays were determined with a metric tape measure.

The bolts, clamps, and shims associated with the various experiment trays were primarily scanned and imaged with M&D SIG System #3; the coordinates for features residing on these pieces of hardware were measured with a metric scale.

Bolt-Hole Registration Example (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	59	947	55	-28
Center	617	949	614	-25
Far Right	1176	952	1180	-24

Fiducial Mark Locations Example (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Left	227	904	230	24
Middle	624	900	596	24
Right	1010	895	1004	25

The next part of each experiment-tray summary contains the detailed image-file list of the features that were photodocumented on the associated experiment tray or LDEF component. The file list are divided into three groups: Experiment-Tray Clamps, Experiment-Tray Flanges, and Exposed Experimental Surfaces. The last four images that appear in each file list are digitized images of a stage micrometer which were taken at the four click-stop magnifications which were utilized by the M&D SIG for photodocumentation of most features.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration
M&D SIG Photos

ARCHIVED MATERIALS:

See Section 4.B

IMPORTANT: The "General Comments List" on the following page applies to all LDEF summary reports. It also appears on page 548.

GENERAL COMMENTS LIST FOR ALL SUMMARY REPORTS

a	Rings around impact feature.
b	Impact feature with front surface spall zone.
c	Impact associated delamination zone.
d	Ejecta spray partially around crater on same surface as crater.
e	Ejecta spray onto adjacent material not co-planar with cratered surface.
f	Impact feature located on tray wall.
g	Impact located on bottom tray surface.
h	Back surface bulged.
i	Back surface spalled.
j	Multi-crater impact event.
k	Apparent material inclusions in impact feature.
l	Secondary craters.
m	Extended fracture zone around impact feature.
n	Magnification = 1.2, field of view = ~9.7 mm.
o	Magnification = 2.4, field of view = ~4.9 mm.
p	Magnification = 5.0, field of view = ~2.4 mm.
q	Magnification = 10.0, field of view = ~1.2 mm.
v	Image rotated 45° clockwise.
w	Image rotated 90° clockwise.
x	Image rotated 180°.
y	Image rotated 45° counter-clockwise.
z	Image rotated 90° counter-clockwise.

3.B. EXPERIMENT-TRAY SUMMARIES (BAYS A01 - H12)

FINAL TRAY REMOVAL SEQUENCE

		FEBRUARY				MARCH																			APRIL	
	TRAY LOCATION	23	26	27	28	1	2	5	6	7	8	9	12	13	14	15	16	19	20	21	22	23	26	27	3	18
1	F02 - C05 - C06	■																								
2	D07 - D08 - D09		■																							
3	F12 - MTM - E04			■																						
4	D04 - D03 - A08 - A09				■																					
5	B10 - C08 - C04 - B01					■																				
6	C09 - C03 - H05 - F10 - F11						■																			
7	F06 - E12 - H09 - H06							■																		
8	B03 - B02 - E01 - F05								■																	
9	A11 - A06 - G06 - F07 - B11									■																
10	B12 - A05 - A04 - A03										■															
11	E08 - D11 - D10 - E03											■														
12	E09												■													
13	B09 - C02 - G02 - B08													■												
14	F08 - H07 - E06														■											
15	G12 - H12 - H03 - D12															■										
16	D02 - H11 - G10 - D06																■									
17	C11 - E05 - F01 - E04																	■								
18	A07 - C07 - A01																		■							
19	C12 - A10 - A12 - B05 - E11																			■						
20	F04 - B06 - D05 - E07 - F03																				■					
21	E10 - G04 - D01 - G08																					■				
22	B07 - A0139A Batteries																						■			
23	A02 - B02 - P0003 - H01 - F12 - P0005 - F09																							■		
24	THERMAL PANELS																								■	
25	C01 - C10																									■

Figure A01-H12-1. Chart showing the date and sequence in which all LDEF trays and miscellaneous hardware were removed.

LDEF LOCATION: A01
EXPERIMENT IDENTIFICATION: A0175
EXPERIMENT TITLE: EVALUATION OF LONG DURATION EXPOSURE TO THE NATURAL SPACE ENVIRONMENT ON GRAPHITE-POLYIMIDE AND GRAPHITE-EPOXY MECHANICAL PROPERTIES
PRINCIPAL INVESTIGATOR: R. VYHNAL
ROCKWELL INTERNATIONAL CORPORATION
TULSA, OKLAHOMA

SUMMARY OF OBSERVATIONS

Tray A01 was a 3"-deep (7.6 cm), passive experiment-tray which was one of two experiment-trays comprising the A0175 experiment. The other tray was located at position A07 and was also totally passive. The A01 experiment consisted of two LaRC-160 graphite-polyimide panels, one Fiberite 934/T-300 graphite-epoxy panel, and one Hexcel F-178/T-300 graphite-polyimide/paper-honeycomb sandwich panel, all of which were rigidly mounted to the experiment tray using ~0.125" thick by 1" (~0.3 cm x 2.5 cm) wide anodized 2024-T3 aluminum retaining strips.

All impact features in aluminum were typical of craters produced in aluminum during laboratory hypervelocity impact tests. However, the impacts on the surface of the black experiment samples were very difficult to see. Since there were approximately equal numbers of features on the aluminum tray flanges and the aluminum retaining strips, it is expected that numerous small impacts were not identified on the graphite-composite experiment sample surfaces due to the difficulty in visually identifying impact features on these materials.

The M&D SIG survey identified a total of 125 features on the A01 experiment tray including the experiment-tray bolts, clamps, shims, flanges, and experiment sample retaining strips, as well as the graphite-polyimide experiment samples. Of the impacts identified, 111 were <0.5 mm in diameter and were not imaged; 13 of the remaining features were craters ranging in diameter from 0.5 mm to 1.1 mm, and one feature was a ~2.3 mm wide spray pattern on the back of the upper tray flange caused by an impact into an LDEF structural longeron. Of the total, fourteen impacts were identified on the eight clamps which held tray A01 in place on LDEF. Of these impacts, two were larger than 0.5 mm in diameter and were photodocumented as ~0.6 mm and ~0.7 mm in diameter, respectively. One impact smaller than 0.5 mm in diameter was identified on the top of the head of a clamp bolt. One feature larger than 0.5 mm in an experiment sample retaining strip could not be imaged, but a 35-mm camera photograph was taken of the impact. Five of the imaged features resided on the tray flanges, as did 25 features which were smaller in diameter than the 0.5 mm threshold. Two of the imaged features resided on the retaining strips; 36 other features on the retaining strips were less than 0.5 mm in diameter. Only four of the imaged features resided on the experiment samples, and only 38 other features were identified on these samples as being smaller than the 0.5 mm threshold, despite the samples having a surface area several orders of magnitude larger than the tray flanges and retaining strips.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	12	25	74	111
>0.5 mm	2	5	7	14
TOTALS	14	30	81	125

The largest impact features identified on tray A01 were (1) an oblique impact ~1.1 mm long by ~0.6 mm wide and a circular impact ~0.9 mm in diameter located on the tray flanges, (2) an oval impact ~0.9 mm by ~0.8 mm located on the retaining strip, 3) a circular impact ~0.6 mm in diameter located on the LaRC-160 graphite-polyimide, and (4) an oblique impact ~1.0 mm long by ~0.7 mm wide located in the Hexcel F-178/T-300 graphite-polyimide/paper-honeycomb sandwich.

Two of the features imaged from the tray flanges were related to impact features on the LDEF structural longeron between tray A01 and tray A12. The first of these was a circular impact ~0.9 mm in diameter which caused a spray pattern on the Bay A, Row 12 longeron. This spray pattern was imaged as feature #2 for the longeron. The second impact feature was an ~2.3 mm wide circular spray pattern on the back of the tray flange which was caused by an impact into the Bay A, Row 12 longeron underneath the lip of the tray flange. This impact was imaged as feature #3 for the longeron, and was surrounded by a secondary circular spray pattern caused by ejecta from the primary spray impact into the back of the tray flange.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft. This inspection identified four features which might be destroyed by attachment of the experiment-tray cover and one feature which would be destroyed by emplacement in the experiment-tray rotator. This latter impact feature was estimated to be ~0.8 mm in diameter. This feature was not examined or photodocumented, nor was it included in the numerical summary given above. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in four locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.0625" (1.6 mm) thick experiment-tray flanges. The ~2.3 mm diameter spray pattern was identified on the back of the tray flange and was correlated to the impact in the Bay A, Row 12 LDEF structural longeron.

DOCUMENTATION:

Examination and photodocumentation of tray A01 was conducted on March 20 and 21, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #1. The bolts, clamps, and shims associated with this tray were scanned and imaged on March 20, 1990 with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	68	960	67	-15
Center	626	960	625	-16
Far Right	1185	959	1182	-16

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC040001.A01	RC040001.A01	28	57		0.7	Al	1
LC070002.A01	RC070002.A01	61	47		0.6	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.A01	RE000001.A01	445	974		0.6	Al	
LE000002.A01	RE000002.A01	742	951		0.7 x 0.6	Al	
LE000003.A01	RE000003.A01	854	995		0.9	Al	*2*
LE000010.A01	RE000010.A01	-8	75		1.1 x 0.6	Al	
LE000011.A01	RE000011.A01	968	995		2.3	Al	*3*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000004.A01	RE000004.A01	94	544		0.5	LaRC-160	*4*
LE000005.A01	RE000005.A01	202	574		0.6	LaRC-160	
LE000006.A01	RE000006.A01	629	496		0.9 x 0.8	Al	
LE000007.A01	RE000007.A01	528	472		0.6	Al	
LE000008.A01	RE000008.A01	749	396		0.8 x 0.5	Honeycomb	
LE000009.A01	RE000009.A01	67	130		1.0 x 0.7	Honeycomb	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Impact into paint specimen on clamp.
2 - Impact caused spray pattern on Bay A, Row 12 longeron which was imaged as longeron feature #2.
3 - Spray pattern only on back of tray flange; caused by impact into LDEF structure.
4 - Wrong coordinates (X = 545, Y = 765) input into image file.

OTHER PHOTODOCUMENTATION:

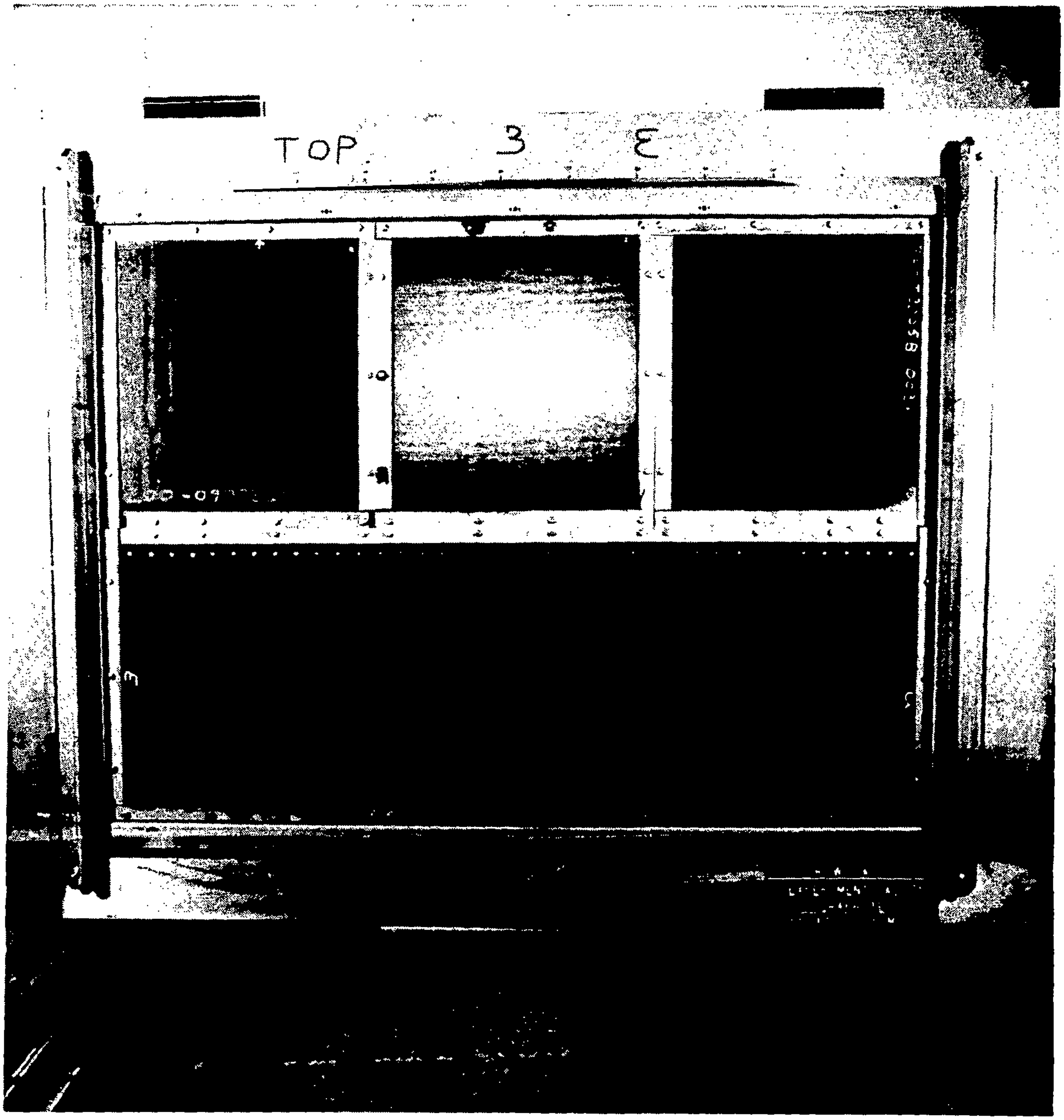
Pre-Flight
On-Orbit - S32-78-29
Pre-Deintegration - KSC-390C-1069.01, KSC-390C-1069.02
Post Deintegration - KSC-390C-2148.05
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - A01C01, A01C03, A01C04, and A01C08
Clamp Bolts - A01S01B
Other - Component A01E00 - Experiment Tray;
Graphite epoxy composite material cores containing features identified above:
Core #LD-114 - Feature #4;
Core #LD-113 - Feature #5;
Core #LD-115 - Feature #8; and
Core #LD-116 - Feature #9.

ACCOMPANYING FIGURES:

Figure A01-1. This post-deintegration view shows the front of the entire A01 experiment tray.



LDEF LOCATION: A02
EXPERIMENT IDENTIFICATION: A0178
EXPERIMENT TITLE: A HIGH RESOLUTION STUDY OF ULTRA-HEAVY COSMIC RAY NUCLEI
PRINCIPAL INVESTIGATOR: D. O'SULLIVAN
DUBLIN INSTITUTE FOR ADVANCED STUDIES
DUBLIN, IRELAND

SUMMARY OF OBSERVATIONS

Bay A02 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46" long (~116.8 cm), 10" (25.4 cm) in diameter, 6063-T6 aluminum cylinders (1.9 mm thick) which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with an ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (space facing) of FEP teflon (~120 μm thick) backed with a thin layer of vapor-deposited silver/inconel (~200 to 300 Å thick), which in turn was backed by DC1200 primer and Chemglaze Z306 black conductive paint (~80 to 100 μm thick). The blankets were attached to a 40-5052 aluminum support frame by ~1" x 2" (~2.5 x 5.1 cm) strips of velcro.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of the resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted teflon material. Commonly, the teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. Many possessed several sharp, distinct rings, while other exhibited a more continuous halo phenomenon where the changes from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impact craters into aluminum.

Large areas of the surface of the A02 thermal blanket were covered with thousands of longitudinal scratches extending tens of centimeters in length and overlying impact features. These scratches were grouped in roughly parallel batches that commonly overlapped each other and propagated from several directions. There were also some apparent low velocity impacts associated with these scratches. In addition, there were several areas (tens of square millimeters in size) of brown/yellow spots with associated bright yellow dots; one such area was imaged (LE000003.A02).

The M&D SIG identified a total of 126 impacts on the A02 experiment on all tray surfaces, including one ~0.4 mm feature on clamp C07 and two small features on the 303 stainless steel hex-head bolts C07C and C08C. Of the remaining 123 impacts, 13 were on the tray flanges, with only one of these >0.5 mm in diameter. Of the 110 impacts identified on the thermal blanket, 103 were <0.3 mm in diameter and were not imaged. The remaining seven features in the blanket ranged in size from 0.3 to 1.0 mm in diameter. Several features on the thermal blanket had no rings in association with the penetration hole. The remaining features

had only small, dark rings around them (see Section 2.B). The various ring structures, when present, were included in the field of view of the optical images of the features.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			103	103
>0.3 mm			7	7
<0.5 mm	3	12		15
>0.5 mm	0	1		1
TOTALS	3	13	110	126

The largest features identified on tray A02 were (1) an ~0.9 x 1.0 mm penetration hole in the thermal blanket and (2) an ~0.5 mm crater located on the experiment-tray flange.

M&D SIG INSPECTIONS

PRE-DEINTEGRATION:

The initial inspection was conducted on February 20, 1990 while the experiment-tray was mounted on the spacecraft. This inspection identified one feature which might be destroyed by attachment of the experiment-tray cover, but it was deemed unnecessary to cut the gasket material for this impact.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

Tray A02 was inspected on March 27, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #3. The tray clamps, bolts and shims were scanned on the same day with M&D SIG System #3, but no features were large enough to be imaged.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	56	948	59	-27
Center	615	949	616	-26
Far Right	1173	950	1174	-26

Fiducial Mark Locations (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Left	167	893	242	17
Middle	618	891	617	24
Right	990	890	1004	20

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000009.A02	RE000009.A02	119	979		0.5	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.A02	RE000001.A02	92	557		0.9 x 1.0	TB	
LE000002.A02	RE000002.A02	193	432		0.5	TB	
LE000003.A02	RE000003.A02	577	497		ND	TB	*1*
AE000003.A02	BE000003.A02	193	432		0.5	TB	
LE000004.A02	RE000004.A02	21	75		0.5	TB	*2*
LE000005.A02	RE000005.A02	1201	174		0.5	TB	
LE000006.A02	RE000006.A02	1211	681		0.4 x 0.5	TB	
LE000007.A02	RE000007.A02	1011	76		0.3	TB	
LE000008.A02	RE000008.A02	414	824		0.5	TB	*2,3*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined
TB - Thermal Blanket (teflon, silver-inconel, binder, and paint).

1 - Contamination area showing bright yellow spots, not an impact feature.
2 - No rings/halos.
3 - Impact occurred over a velcro strip.

OTHER PHOTODOCUMENTATION:

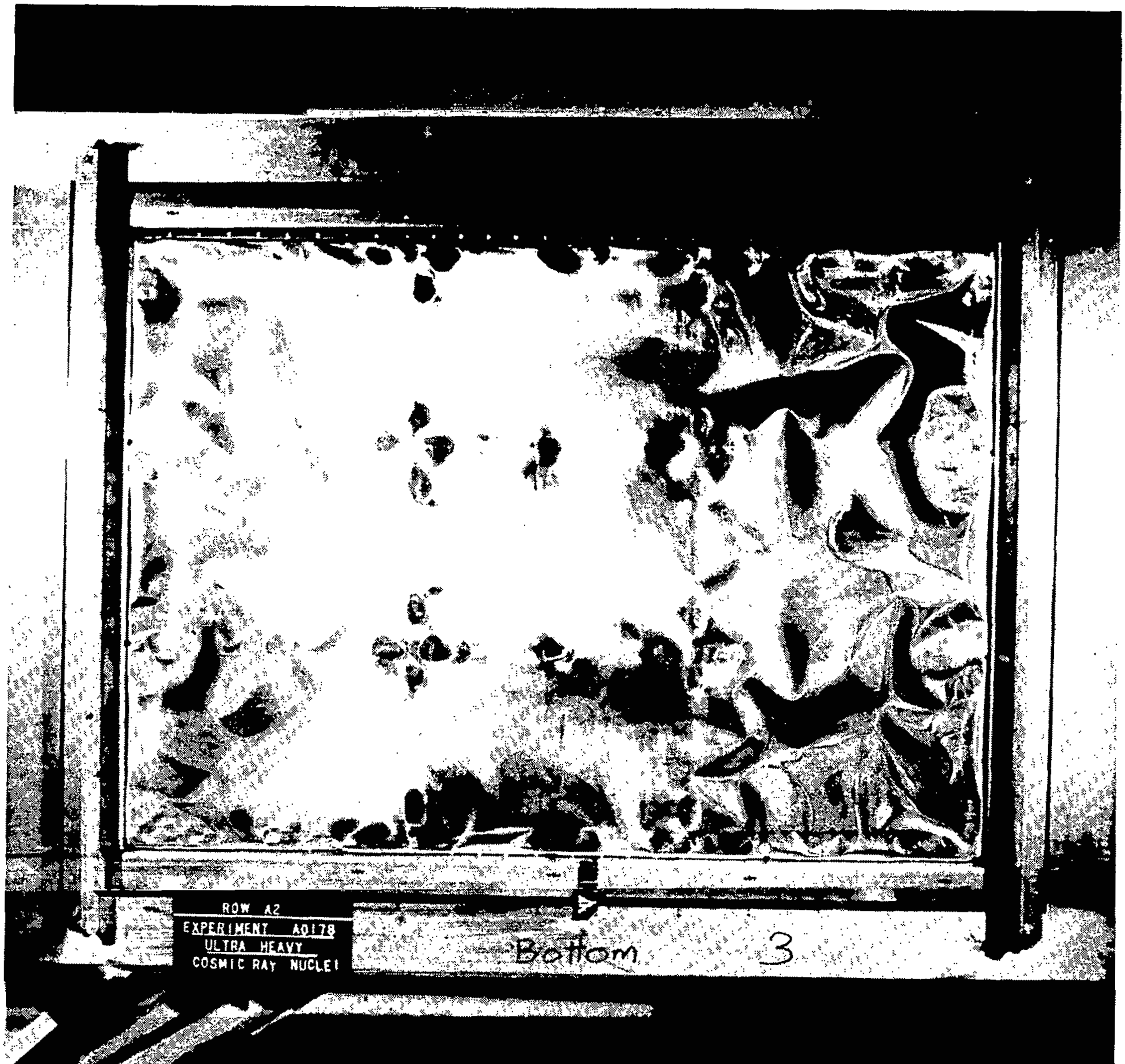
Pre-Flight - 108-KSC-384C-317/5
On-Orbit - S32-77-055
Pre-Deintegration - KSC-390C-1065.07, KSC-390C-1065.08, KSC-390C-1066.06
Post Deintegration - KSC-390C-2333.09
M&D SIG Photos: - S90-43560, S90-43561 - Left 1/3 of Thermal Blanket; front- and back views.
S90-43562, S90-43563 - Center 1/3 of Thermal Blanket; front- and back views.
S90-43564, S90-43565 - Right 1/3 of Thermal Blanket; front- and back views

ARCHIVED MATERIALS:

Clamps - A02C01, A02C03, A02C05 and A02C06
Clamp Bolts - A02S07C and A02S08C
Thermal Blanket - (A02E00A) The U.S. third (minus the Materials SIG specimen) reside at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds (minus the Materials SIG grounding-strap specimen) is being archived at ESTEC in The Netherlands. Each blanket third was marked with two small crosses (see Fiducial Mark table above) for indexing and reconstruction purposes.

ACCOMPANYING FIGURES:

Figure A02-1. This post-deintegration view shows the front of the entire A02 experiment thermal blanket. *Fleur-de-lis* patterns across the blanket are surface expressions of the velcro attachment points to the underlying aluminum frame.


ROW A2
EXPERIMENT A0178
ULTRA HEAVY
COSMIC RAY NUCLEI
Bottom 3

LDEF LOCATION: A03
EXPERIMENT IDENTIFICATION: A0187-1
EXPERIMENT TITLE: CHEMISTRY OF MICROMETEOROIDS
PRINCIPAL INVESTIGATOR: F. HÖRZ
SN2 NASA JOHNSON SPACE CENTER
HOUSTON, TEXAS 77058

SUMMARY OF OBSERVATIONS

Bay A03 was occupied by a 12"-deep (7.6 cm), active experiment tray that was one of two surfaces composing the A0187-1 experiment; the other tray was located at position A11 and consisted of totally passive aluminum collectors. This tray was considered active in that it consisted of two sets of clam shells that were set to open on mission day 10, following the deployment of the LDEF spacecraft, and to close on mission day 308 prior to the spacecraft's retrieval. The predominant collector surfaces (*i.e.*, seven of the eight exposed panels) on experiment-tray A03 were 99.99 percent pure gold sheets 0.5 mm thick yielding an exposed surface area of 0.85 m^2; each of the eight panels measured some 57 x 20.6 cm in size. The eighth panel exposed a variety of smaller surfaces (*i.e.*, eight surfaces ~6.5 x 20.6 x 0.5 cm, each) consisting of >99.0 percent pure Al, Ti, Be, Zr, or C, as well as one surface of kapton and two porous teflon filters.

The initial exposure scenario for these surfaces was considered advantageous for two primary reasons: (1) the controlled exposure time would reduce the risk of contamination *via* deployment, retrieval, and processing and (2) the time-dependant meteoroid flux information could be used to address variances in the general low-Earth orbit meteoroid flux over the 5.7 years total exposure of the LDEF spacecraft. Unfortunately, tray A03 was open when recovery occurred; total exposure of the surfaces is unknown as of the time of this writing.

The M&D SIG survey identified a total of 79 impact features on the experiment-tray surfaces which include the surfaces inside the tray (*i.e.*, exposed while the clam shells were in the closed position), the tray flanges, the clamps, the stainless steel bolts, as well as the various collectors surfaces (see above). Of these, 73 were <0.5 mm in diameter and were not imaged (68 of which resided on the dedicated meteoroid detector surfaces); the remaining 6 features ranged in diameter from 0.5 mm to 1.0 mm. One impact each was found on three of the eight tray clamps (C02, C03 & C05), as well as one feature on bolt C03B; the feature on clamp C05 was on the edge of a clamp). Only three of the imaged features resided on the Au-meteoroid surfaces, one on the experiment-tray lips, and two on surfaces within the tray that were exposed while the clam shells were in the closed position. All features were typical of craters produced during laboratory hypervelocity impact test.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	4			72*
>0.5 mm		2	3	7
TOTALS	4			79

* - The locations of the "Too Smalls" were not documented.

The largest impact features identified on tray A03 were (1) an ~1.0 mm diameter crater located on the pure Au collector surface and (2) an ~0.8 mm diameter crater found located on the experiment-tray flange.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 20, 1990 while the experiment-tray was mounted on the spacecraft and identified no features that might be damaged or destroyed by the emplacement of the experiment-tray cover, and only one feature that could be damaged by the removal of the clamps and bolts holding the tray on to the spacecraft. Therefore, no alterations to the tray-cover gasket were required, but the use of an open-end wrench was requested for the removal of bolts C03B.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick aluminum experiment-tray flanges.

DOCUMENTATION:

Tray A03 was examined and photodocumented on March 8, 1990 in the vertical position utilizing M&D SIG System #2 while mounted to one of the tubular JSC rotators. As a result of a JSC rotator being used, an M&D SIG Coordinate Registration System could not be utilized in feature coordinate registration; feature locations were measured with a metric tape measure. Following closure of the experimental clam shells the experiment tray was returned to the M&D SIG area for examination and documentation of features residing in the inner tray areas. This second examination was conducted on March 13, 1990 using M&D SIG System #1, while coordinates were again measured with a metric tape measure. The bolts, clamps, and shims associated with this tray were scanned with M&D SIG System #3, although no features were found to be large enough to image.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000003.A03	RE000003.A03	1083	-43		0.7	Al	
LE000005.A03	RE000005.A03	964	908	60	0.8	Al	*1*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.A03	RE000001.A03	1135	582		1.0	Au	
LE000002.A03	RE000002.A03	1182	48		0.7	Au	
LE000004.A03	RE000004.A03	422	125		0.9	Au	
LE000006.A03	RE000006.A03	181	156	355	0.8	Al	*2*, *g*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Image taken at 45° from normal of crater.
2 - Imaged using 350 mm lower objective on microscope.

OTHER PHOTODOCUMENTATION:

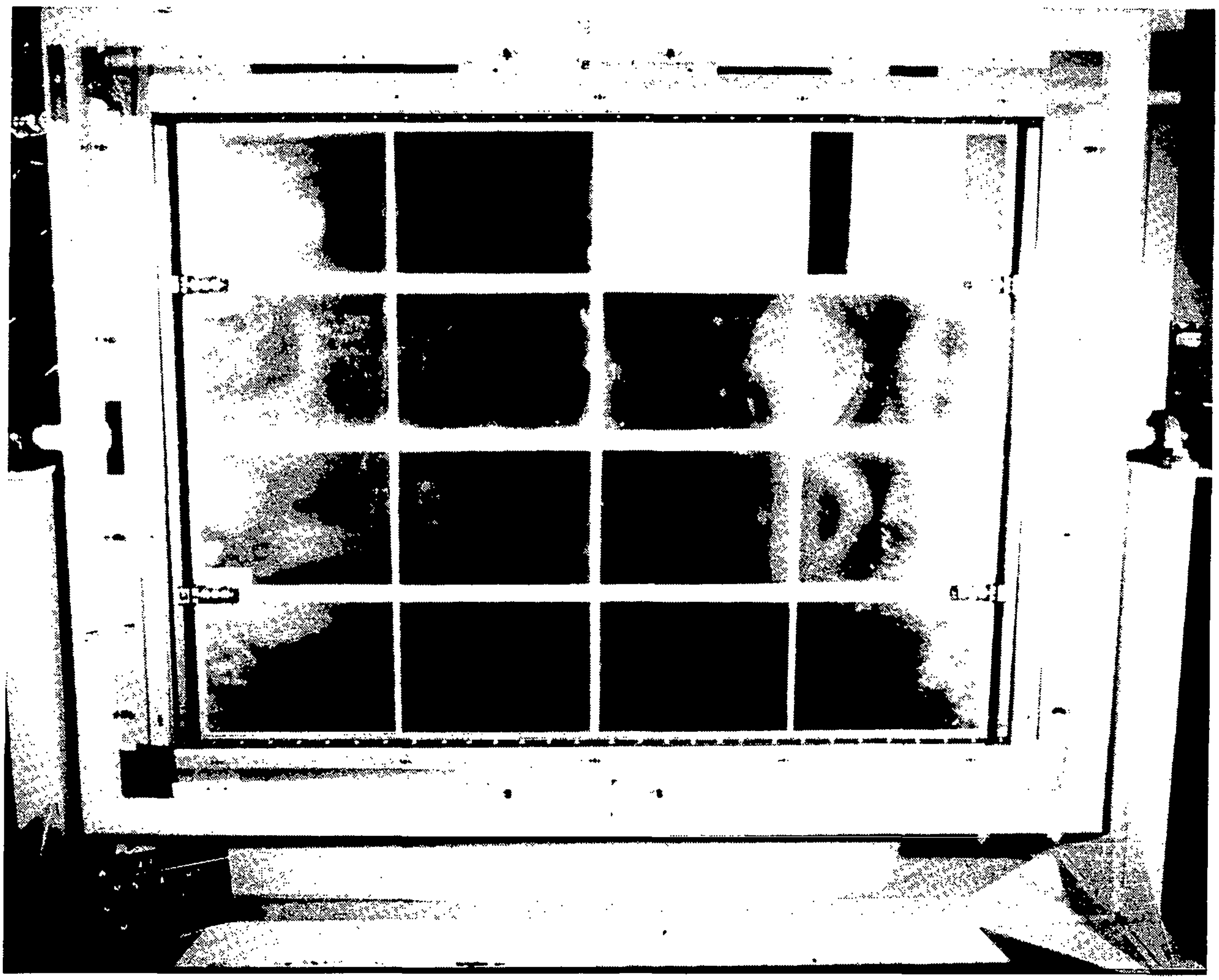
Pre-Flight
On-Orbit - S32-77-055
Pre-Deintegration - KSC-390C-1065.01, KSC-390C-1065.02, KSC-390C-834.04
Post Deintegration - KSC-390C-1764.10, KSC-390C-1762.01, KSC-390C-1762.02
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - A03C01, A03C03, A03C04, and A03C06
Clamp Bolts - A03S03B, A03S07B, and A03S07C

ACCOMPANYING FIGURES:

Figure A03-1. This post-deintegration view shows the front of the entire A03 experiment tray, showing the two aluminum base-plates.



LDEF LOCATION: A04
EXPERIMENT IDENTIFICATION: A0178
EXPERIMENT TITLE: A HIGH-RESOLUTION STUDY OF ULTRA-HEAVY COSMIC-RAY NUCLEI
PRINCIPAL INVESTIGATOR: D. O'SULLIVAN
DUBLIN INSTITUTE FOR ADVANCED STUDIES
DUBLIN, IRELAND

SUMMARY OF OBSERVATIONS

Bay A04 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46" long (~116.8 cm), 10" (25.4 cm) in diameter, 6063-T6 aluminum cylinders (1.9 mm thick) which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with an ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (space facing) of FEP teflon (~120 μm thick) backed with a thin layer of vapor-deposited silver/inconel (~200 to 300 Å thick), which in turn was backed by DC1200 primer and Chemglaze Z306 black conductive paint (~80 to 100 μm thick). The blankets were attached to a 40-5052 aluminum support frame by ~1" x 2" (~2.5 x 5.1 cm) strips of velcro.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of the resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted teflon material. Commonly, the teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. Many possessed several sharp, distinct rings, while other exhibited a more continuous halo phenomenon where the changes from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impact craters into aluminum.

The M&D SIG identified a total of 74 impacts on the A04 experiment on all tray surfaces including nine features <0.5 mm on tray clamps, one of which occurred on the side of clamp C05. Of the remaining 65 features, seven were located on the experiment-tray flanges, with only one of these >0.5 mm in diameter, and one that was on the inner-tray wall in a position that precluded imaging. Of the 57 features identified on the thermal blanket, 48 were <0.3 mm in diameter and were not imaged. The remaining nine features on the blanket ranged in size from 0.2 mm to 0.5 mm. One small feature ~0.2 mm was imaged because of some associated debris on one side (LE000004.A04). All of the penetration features had an associated ring structure surrounding them that was included in the field of view of the optical images of the features.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			49	49
>0.3 mm			8	8
<0.5 mm	9	6		15
>0.5 mm		2		2
TOTALS	9	8	57	74

The largest features identified on tray A04 were (1) an ~0.9 mm diameter crater on the experiment-tray flange and (2) an ~0.5 mm penetration located on the thermal blanket.

M&D SIG INSPECTIONS

PRE-DEINTEGRATION:

The initial inspection was conducted on February 22, 1990 while the experiment-tray was mounted on the spacecraft and identified two features that might be damaged or destroyed by the emplacement of the experiment-tray cover, and one feature that could be damaged placement of the experiment-tray in the rotator. The latter impact feature was not examined or photodocumented, nor was it included in the numerical summary given above. No alterations to the tray-cover gasket were required.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick aluminum experiment-tray flanges.

DOCUMENTATION:

Tray A04 was inspected on March 8, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #3. The clamps, bolts and shims associated with this tray were scanned with M&D SIG System #3, although no features were found to be large enough to image.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Left	56	948	57	-27
Middle	614	949	615	-26
Right	1172	951	1172	-24

Fiducial Mark Locations (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Left	221	906	235	24
Middle	618	899	564	27
Right	1009	893	1012	22

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.A04	RE000001.A04	703	976		0.9	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.A04	RE000002.A04	559	844		0.2 x 0.3	TB	
LE000003.A04	RE000003.A04	275	629		0.3	TB	
LE000004.A04	RE000004.A04	568	595		0.2	TB	d
LE000005.A04	RE000005.A04	974	493		0.3	TB	
LE000006.A04	RE000006.A04	1016	391		0.3	TB	
LE000007.A04	RE000007.A04	851	212		0.2 x 0.3	TB	
LE000008.A04	RE000008.A04	1159	85		0.4	TB	
LE000009.A04	RE000009.A04	207	192		0.5	TB	
LE000010.A04	RE000010.A04	153	69		0.4	TB	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

TB - Thermal Blanket (teflon, silver-inconel, binder, and paint).

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC384C-403/3
On-Orbit - S32-77-023
Pre-Deintegration - KSC-390C-1065.06, KSC-390C-1065.04, KSC-390C-832.07
Post Deintegration - KSC-390C-1743.05
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - A04C03, A04C05, A04C06 and A04C08
Thermal Blanket - (A04E00A) The U.S. third (minus the Materials SIG specimen) reside at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds (minus the Materials SIG grounding-strap specimen) is being archived at ESTEC in The Netherlands. Each blanket third was marked with two small crosses (see Fiducial Mark table above) for indexing and reconstruction purposes.

LDEF LOCATION:	**A05**
TRAY IDENTIFICATION:	**S0001**
EXPERIMENT PURPOSE:	**SPACE DEBRIS IMPACT EXPERIMENT**
PRINCIPAL INVESTIGATOR:	**D. HUMES** **493 NASA LANGLEY RESEARCH CENTER** **HAMPTON, VIRGINIA 23665**

SUMMARY OF OBSERVATIONS

Bay A05 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays that were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 225 features on the A05 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of the 225 impacts found, 213 were <0.5 mm and were not imaged, the remaining 12 that were imaged ranged in diameter from 0.4 mm to 1.5 mm. Of the 213 impacts not imaged due to the impact size being less than the threshold limit of 0.5 mm, 206 were located on the experimental aluminum surface, five were located on clamps (C02, C03, C06, and C08), and the remaining two were located on the experiment-tray flanges. Of the 12 imaged impacts, five were located on the tray flanges and ranged in diameter from 0.7 mm to 1.5 mm in diameter, one was located on clamp C07 and was below the 0.5 mm criteria, and the remaining six impacts were located on the aluminum tray surface and ranged in diameter from 0.6 mm to 1.5 mm in diameter. All features were typical of craters produced in aluminum during laboratory hypervelocity impact tests.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	6			214*
>0.5 mm	0	5	6	11
TOTALS	6			225

* - The locations of the "Too Smalls" were not documented.

The largest impact features identified on tray A05 were (1) a circular impact ~1.5 mm in diameter with a very large spray pattern located on the bottom tray flange wall, (2) a circular impact ~1.5 mm in diameter located on the top tray flange wall, and (3) a circular impact ~1.5 mm in diameter located on the aluminum tray surface.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 22, 1990 while the experiment-tray was mounted on the spacecraft and the M&D SIG identified five features that might be damaged by the placement of the experiment-tray cover and one additional feature that could be damaged or destroyed by the placement of the experiment tray within the experiment tray stand. The latter impact feature was not examined or

photodocumented, nor was it included in the numerical summary given above. In an effort to protect the more interesting feature within the experiment-tray cover area, the cover gasket was cut in one location to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations of the 0.0625" (1.6 mm) thick experiment-tray flanges and no bulges or spalls on the back of the tray flanges. There were shadow features on the black painted back surface of the experiment tray.

DOCUMENTATION:

Examination and photodocumentation of tray A05 was conducted on March 8, 1990 in the horizontal position utilizing M&D SIG System #1 and impact coordinates were determined using a metric tape measure. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured using a small metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experimental-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC070001.A05	RC070001.A05	80	18		0.4	Al	*k*

Impact Features Imaged on Experimental-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000003.A05	RE000003.A05	1051	954	45	1.5	Al	*1,f,*
LE000004.A05	RE000004.A05	762	0	32	1.5	Al	*1,d,f*
LE000005.A05	RE000005.A05	438	0	67	0.8	Al	*1,f*
LE000006.A05	RE000006.A05	140	960		0.7	Al	
LE000007.A05	RE000007.A05	390	980		0.8	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.A05	RE000001.A05	864	878		1.5	Al	
LE000002.A05	RE000002.A05	1086	543		0.6	Al	
LE000008.A05	RE000008.A05	31	810		0.7	Al	
LE000009.A05	RE000009.A05	86	633		0.7	Al	
LE000010.A05	RE000010.A05	32	319		0.9	Al	
LE000011.A05	RE000011.A05	263	112		0.7	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Image taken at 30° from normal.

OTHER PHOTODOCUMENTATION:

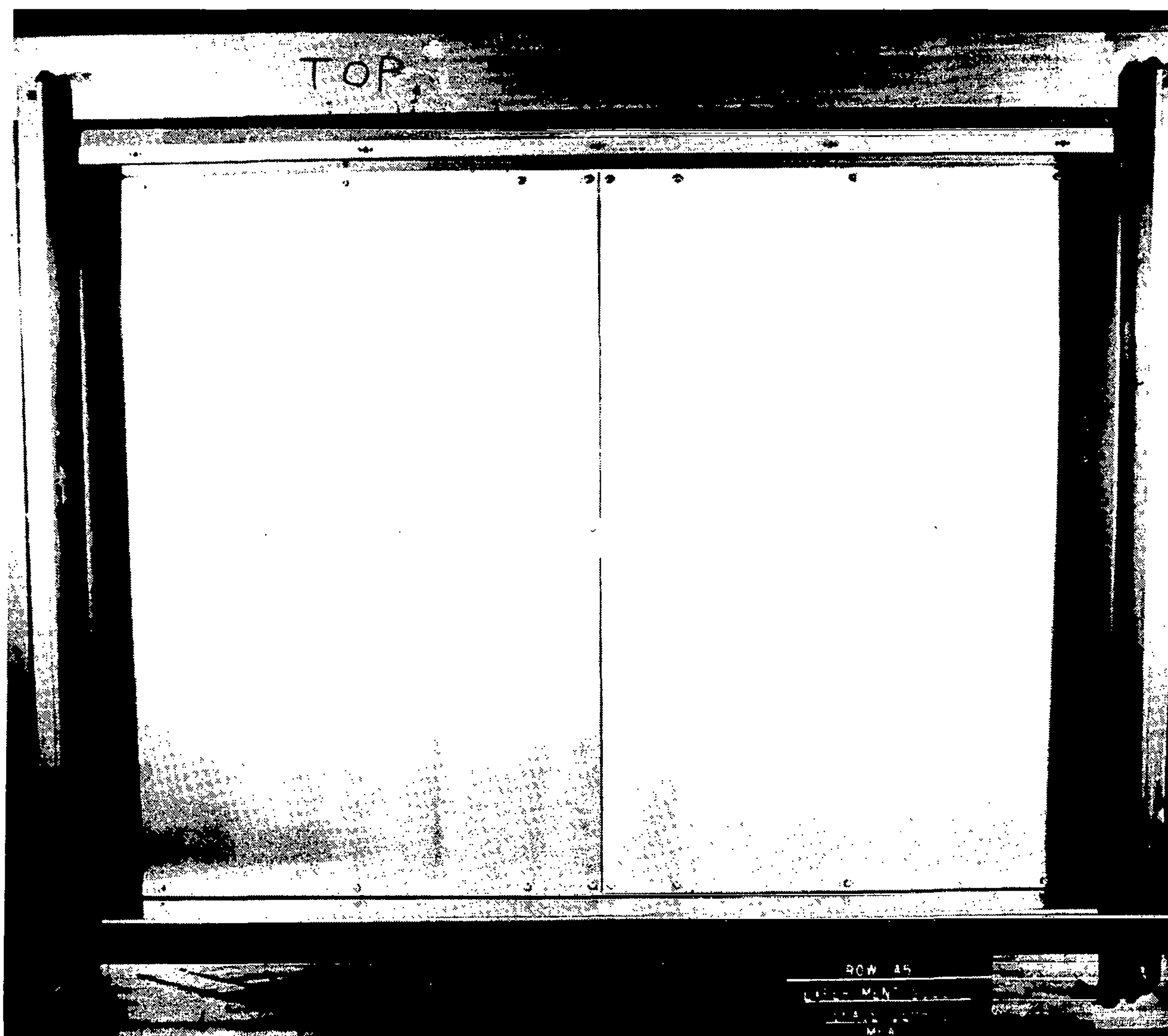
Pre-Flight - L-83-06439
On-Orbit - S32-76-79
Pre-deintegration - KSC-390C-1035.09, KSC-390C-1035.10, KSC-390C-1035.11
Post Deintegration - KSC-390C-2159.01
M&D-SIG Photos - None

ARCHIVED MATERIALS:

Clamps - A05C03, A05C06, A05C07, and A05C08

ACCOMPANYING FIGURES:

Figure A05-1. This post-deintegration view shows the front of the entire A05 experiment tray.



LDEF LOCATION: A06
EXPERIMENT IDENTIFICATION: S0001
EXPERIMENT TITLE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES
493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay A06 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays that were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 147 features on the A06 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of these, 133 features from all surfaces were found to be less than the 0.5 mm photodocumentation threshold. Of the 133 features too small to photodocument, 115 were located on the aluminum tray surface, 14 were located on the tray flange, and four were located on the clamps, bolts and shims. Fifteen features were photodocumented from the aluminum collector surfaces, two of which were <0.5 mm, nine of which were between 0.5 mm and 1.0 mm in diameter, and four features that were between 1.0 mm and 1.5 mm in diameter. All features exhibited characteristics typical of craters formed in aluminum during laboratory hypervelocity impact experiments.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	4	14	115	133
>0.5 mm			14	14
TOTALS	4	14	129	147

The largest impact feature identified on tray A06 was a circular crater ~1.2 mm in diameter located on the aluminum experimental tray surface.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 22, 1990 while the experiment-tray was mounted on the spacecraft and the M&D SIG identified two features that might be damaged by the placement of the experiment-tray cover and five additional features that could be damaged or destroyed by the placement of the experiment-tray within the experiment-tray stand. The latter impact features were not examined or photodocumented, nor were they included in the numerical summary given above. No alterations to the tray-cover gasket were required.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges or spallation features on the 0.0625" (1.6 mm) thick experiment-tray flanges or backside.

DOCUMENTATION:

Examination and photodocumentation of tray A06 was conducted on March 7, 1990 in the horizontal position utilizing M&D SIG System #2. The bolts, clamps and shims associated with this tray were scanned with M&D SIG System #3. The coordinates for all features associated with this tray were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.A06	RE000001.A06	13	184		0.7	Al	
LE000002.A06	RE000002.A06	546	367		0.4	Al	
LE000003.A06	RE000003.A06	428	755		1.1	Al	*w*
LE000004.A06	RE000004.A06	412	789		1.0	Al	*w*
LE000005.A06	RE000005.A06	200	815		0.6 x 0.7	Al	*w*
LE000006.A06	RE000006.A06	733	842		0.7	Al	*x*
LE000007.A06	RE000007.A06	1079	916		0.7	Al	*x*
LE000008.A06	RE000008.A06	1004	756		0.6	Al	*x*
LE000009.A06	RE000009.A06	1166	676		0.6	Al	*x*
LE000010.A06	RE000010.A06	1045	520		0.3	Al	*1,d,x*
LE000011.A06	RE000011.A06	1145	515		1.2	Al	*x*
LE000012.A06	RE000012.A06	660	410		0.5	Al	
LE000013.A06	RE000013.A06	1030	90		0.7	Al	
LE000014.A06	RE000014.A06	1180	110		1.0	Al	
LE000015.A06	RE000015.A06	1050	350		0.4 x 0.5	Al	*2,3,d*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Spall feature measures ~0.5 mm.
2 - Spall feature measures ~0.9 x 1.0 mm.
3 - On Navigational Target.

OTHER PHOTODOCUMENTATION:

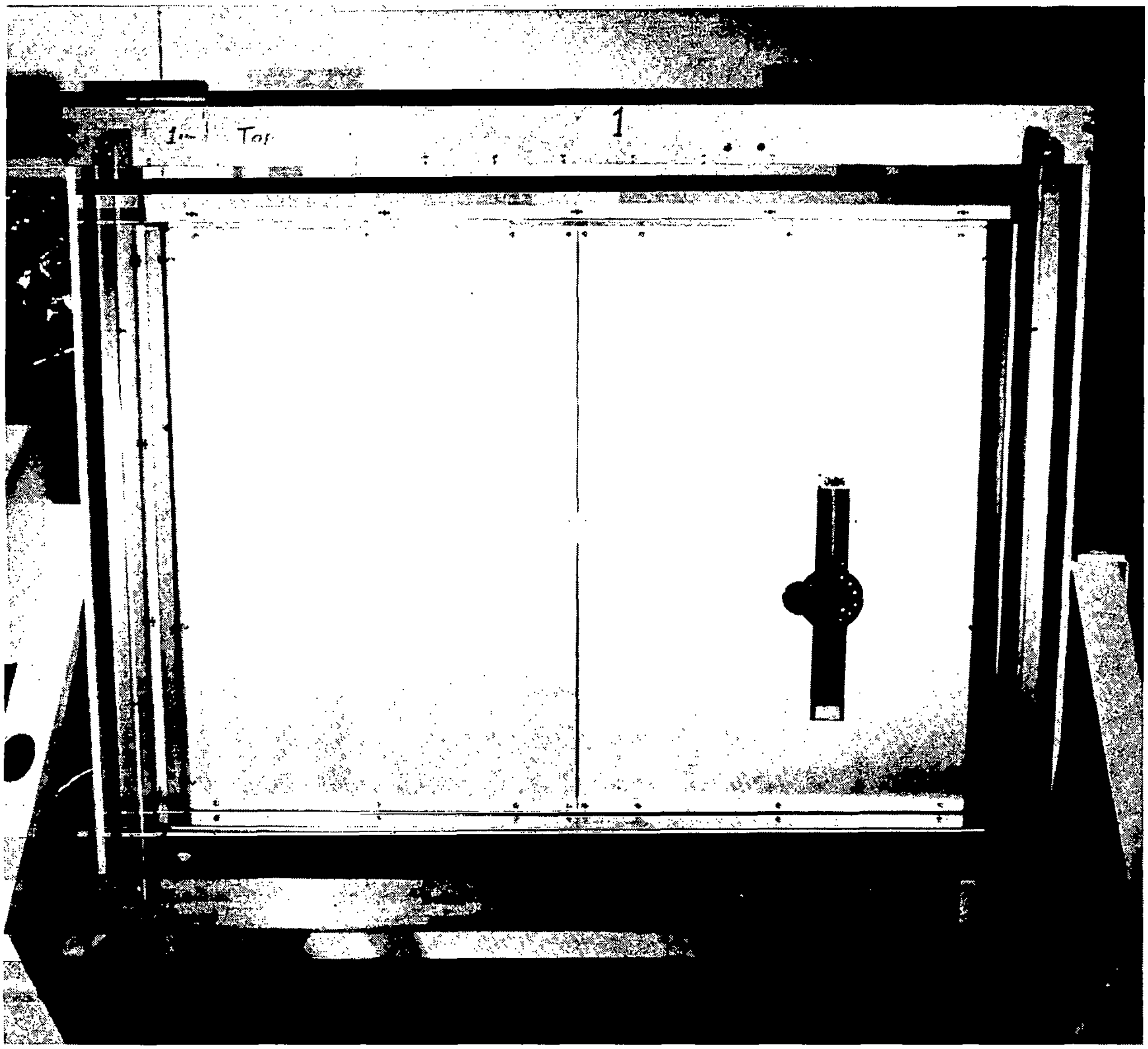
Pre-Flight - L-84-7210, L-83-06439
On-Orbit - S32-76-87
Pre-Deintegration - KSC-390C-1033.01, KSC-390C-1033.02, KSC-390C-1035.01, KSC-390C-1035.03
Post Deintegration - KSC-390C-1703.07
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - A06C04, A06C05, A06C06, and A06C08

ACCOMPANYING FIGURES:

Figure A06-1. This post-deintegration view shows the front of the entire A06 experiment tray. The navigational target is located on the right side of the aluminum tray.



LDEF LOCATION: A07
TRAY IDENTIFICATION: A0175
EXPERIMENT TITLE: EVALUATION OF LONG DURATION EXPOSURE TO THE NATURAL SPACE ENVIRONMENT ON GRAPHITE-POLYIMIDE AND GRAPHITE-EPOXY MECHANICAL PROPERTIES
PRINCIPAL INVESTIGATOR: R. VYHNAL
ROCKWELL INTERNATIONAL CORPORATION
TULSA, OKLAHOMA

SUMMARY OF OBSERVATIONS

Tray A07 was a 3"-deep (7.6 cm), totally passive experiment-tray which was one of two experiment-trays comprising the A0175 experiment. The other tray was located at position A01 and was also totally passive. The A0175 experiment was designed to test graphite-polyimide materials in a space environment and evaluate laminar micro-cracking and crack propagation, and to eliminate any concerns associated with "unknowns". The A07 experiment consisted of two Hexel F-178/T-300 graphite-polyimide laminate panels, one precured and one cocured, and one precured PMR-15 graphite-polyimide laminate panel. The three panels on A07 were (15.20" X 36.14" X 0.088") in dimension (38.6 x 91.7 x 0.2 cm) and were rigidly mounted to the experiment tray using 1" (2.5 cm) wide anodized aluminum retaining strips.

The impacts on the surface of the black graphite-polyimide were very difficult to see. Upon initial visual inspection of the experiment there looked to be a lot of impacts into the graphite-polyimide surfaces but on closer inspection with the microscope, these impacts turned out to be small tears in the surface. Since there were approximately equals numbers of features on the aluminum tray flanges and the aluminum retaining strips, it is expected that numerous small impacts were not identified on the graphite-polyimide experiment sample surfaces due to the difficulty in visually identifying impact features on these materials.

The M&D SIG survey identified a total of 236 features on the A07 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well the graphite-polyimide experiment surfaces. Of the 236 impacts found, 197 were <0.5 mm and were not imaged due to the impact feature size being less that the 0.5 mm documentation criteria, 18 features were located on the experiment-tray clamps, 51 were located on the experiment-tray flanges, and the remaining 136 were located on the graphite-polyimide experimental surfaces. The remaining 39 features that were imaged ranged in diameter from 0.3 mm to 2.3 mm. Of the 39 imaged impacts, seven were located on the tray flanges and ranged in size from 0.5 mm to 0.9 mm in diameter, one was located on clamp C03 and measured ~0.6 mm in diameter, 11 were located on the aluminum retaining strips, and the remaining 20 impacts were located on the graphite-polyimide tray surface and ranged in size from 0.4 mm to 2.3 mm in diameter. All features in aluminum were typical of craters produced in aluminum during laboratory hypervelocity impact tests.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	18	51	136	205
>0.5 mm	1	6	24	31
TOTALS	19	57	160	236

The largest impact features identified on tray A07 were (1) an oblique impact ~2.3 x 0.7 mm located on the surface of the graphite-polyimide, (2) a circular impact ~1.1 mm in diameter located on the aluminum

retainer strip, and (3) a circular impact ~0.9 mm in diameter located on the tray flange. Feature (LE000015.A07) was imaged on the upper right edge of the aluminum retainer strip with a secondary ejecta into the tray lip measuring ~5.5 mm in diameter.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft and the M&D SIG identified seven features that might be damaged by the placement of the experiment-tray cover and two additional features that could be damaged or destroyed by the placement of the experiment tray within the experiment tray stand. The latter impact features were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in five locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations of the 0.0625" (1.6 mm) thick experiment-tray flanges and no bulges or spalls on the back of the tray flanges.

DOCUMENTATION:

On March 20, 1990 the A0175 experiment tray was inspected and photodocumented in the vertical position utilizing M&D SIG System #2 and impact coordinates were determined using Coordinate Registration System #1. The detailed inspection of the clamps and bolts was also performed on March 20, 1990 on M&D SIG System #3 and impact coordinates were determined using a metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	67	960	66	-15
Center	626	960	625	-15
Far Right	1185	960	1184	-14

Impact Features Imaged on Experimental-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC030001.A07	RC030001.A07	108	32		0.6	Al	

Impact Features Imaged on Experimental-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.A07	RE000001.A07	308	966		0.6	Al	
LE000002.A07	RE000002.A07	792	962		0.5 x 0.6	Al	
LE000003.A07	RE000003.A07	1073	972		0.5	Al	
LE000035.A07	RE000035.A07	246	-12		0.7	Al	1

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000036.A07	RE000036.A07	645	-7		0.9	Al	*1*
LE000037.A07	RE000037.A07	868	-45		0.7	Al	*1*
LE000038.A07	RE000038.A07	348	-33		0.7	Al	*1*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000004.A07	RE000004.A07	302	924		0.5	GR-Poly	
LE000005.A07	RE000005.A07	990	927		0.6	GR-Poly	
LE000006.A07	RE000006.A07	102	724		0.3	GR-Poly	
LE000007.A07	RE000007.A07	164	770		0.5 x 0.6	GR-Poly	
LE000008.A07	RE000008.A07	294	796		0.7 x 0.8	GR-Poly	
LE000009.A07	RE000009.A07	343	728		0.4	GR-Poly	
LE000010.A07	RE000010.A07	576	822		0.7	GR-Poly	*j*
LE000011.A07	RE000011.A07	634	712		0.5	GR-Poly	
LE000012.A07	RE000012.A07	696	748		0.4 x 0.5	GR-Poly	
LE000013.A07	RE000013.A07	718	793		0.6 x 1.1	GR-Poly	
LE000014.A07	RE000014.A07	780	713		0.7	GR-Poly	
LE000015.A07	RE000015.A07	843	947		0.7	GR-Poly	*d,e*
LE000016.A07	RE000016.A07	1162	589		0.5	GR-Poly	
LE000017.A07	RE000017.A07	972	557		0.7 x 2.3	GR-Poly	
LE000018.A07	RE000018.A07	963	533		0.7	GR-Poly	
LE000019.A07	RE000019.A07	946	496		0.6	GR-Poly	
LE000020.A07	RE000020.A07	490	394		0.6	GR-Poly	
LE000021.A07	RE000021.A07	1246	514		0.9	GR-Poly	
LE000022.A07	RE000022.A07	409	513		0.5	GR-Poly	
LE000023.A07	RE000023.A07	422	505		0.7	GR-Poly	
LE000024.A07	RE000024.A07	443	415		1.0	GR-Poly	
LE000025.A07	RE000025.A07	442	350		0.9	GR-Poly	
LE000026.A07	RE000026.A07	431	274		1.1	GR-Poly	
LE000027.A07	RE000027.A07	1230	213		0.8	GR-Poly	
LE000028.A07	RE000028.A07	1208	185		0.5	GR-Poly	
LE000029.A07	RE000029.A07	1175	135		0.7	GR-Poly	
LE000030.A07	RE000030.A07	749	85		0.2 x 0.4	GR-Poly	*k*
LE000031.A07	RE000031.A07	625	55		0.4 x 0.5	GR-Poly	
LE000032.A07	RE000032.A07	682	60		0.5 x 0.7	GR-Poly	
LE000033.A07	RE000033.A07	1142	-1		0.6	GR-Poly	*1*
LE000034.A07	RE000034.A07	968	16		0.9	GR-Poly	*1*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

GR-Poly - Graphite-Polyimide

1 = 36° tray angle, 23° microscope angle.

OTHER PHOTODOCUMENTATION:

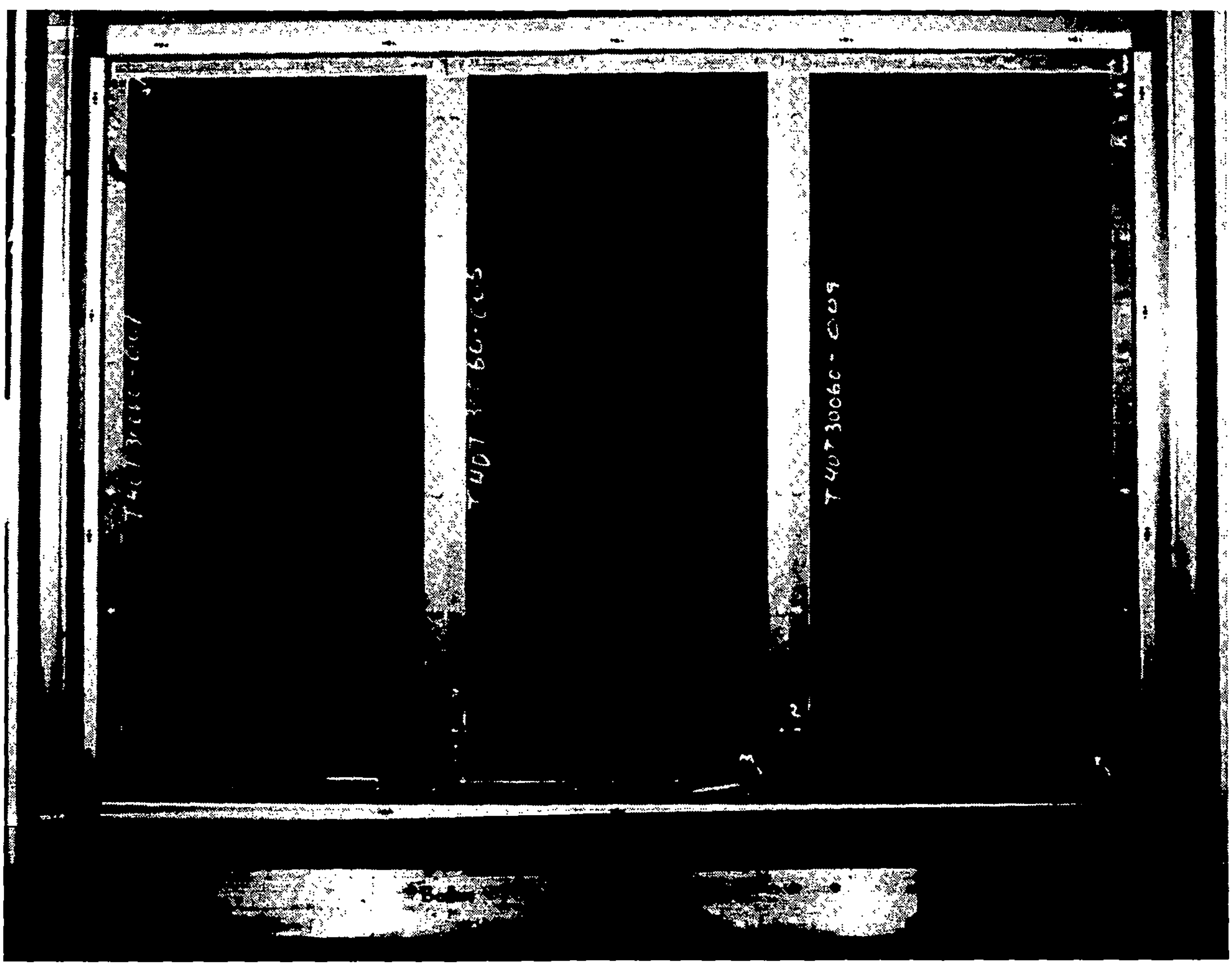
Pre-Flight - L-84-7071
On-Orbit - S32-76-95
Pre-deintegration - KSC-390C-1032.07, KSC-390C-1023.08, KSC-390C-1032.09
Post Deintegration - KSC-390C-2145.09
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - A07C01, A07C03, A07C06, and A07C08
Other - Experiment tray (A07E00) and aluminum retainer strips without experimental surfaces.
LD-117 (A07E00,8) - Feature in graphite composite.
LD-118 (A07E00,14) - Feature in graphite composite.
LD-119 (A07E00,17) - Feature in graphite composite.

ACCOMPANYING FIGURES:

Figure A07-1. This post-deintegration view shows the front of the entire A07 experiment tray, showing the large sheets of graphite composites.



LDEF LOCATION:	**A08**
EXPERIMENT IDENTIFICATION:	**A0171**
EXPERIMENT TITLE:	**SOLAR-ARRAY-MATERIALS PASSIVE LDEF EXPERIMENT**
PRINCIPAL INVESTIGATOR:	**A. WHITAKER CODE EH11 NASA MARSHALL SPACE FLIGHT CENTER HUNTSVILLE, ALABAMA 35812**

SUMMARY OF OBSERVATIONS

Bay A08 was a passive experiment-tray which contained experiment A0171, the Solar-Array-Materials Passive LDEF Experiment. The A0171 experiment hardware consisted of numerous solar cells, solar cell covers, solar cell modules and assemblies, and solar array materials, including composites, thin films, thermal plastics, structural films, resins and metals. The experiment samples were mounted on 0.19" (4.8 mm) thick chromic anodized aluminum plates, mounted to the bottom of the 3"-deep (7.6 cm) peripheral trays. Four solar cell modules were attached to the aluminum plates by thin (~0.005" thick [~0.1 mm]) Kapton films, with the copper interconnects (the back sides of the solar cell modules) exposed to space. All but one of these were lost in space due to atomic oxygen erosion of the Kapton mounting films. The last one was loose when LDEF was retrieved, holding onto the spacecraft by only its silver soldered interconnects. It fell off the spacecraft during the landing or ferry flight of the Shuttle *Columbia*, and was recovered from the Shuttle Bay after the ferry flight to Kennedy Space Center. The solar cell module was not handled properly (*i.e.* it was not kept flat but was folded) after retrieval and during shipment to the Spacecraft Encapsulation and Assembly Facility (SAEF II) with LDEF. Also, while examining this solar cell module, the M&D SIG A-Team dropped the module onto the floor. The Principal Investigator observed these operations and after this incident, the module was handled properly.

Bay A08 showed two primary types of impact morphology. The impacts into crystalline specimens, like glass, created deep well-like depressions in the center of the impact features with a surrounding outer spallation region, sometimes accompanied by substrate fracture. The well-like depression diameters were recorded as the crater diameters. Impacts into metals were typical of craters produced during laboratory hypervelocity impact tests.

Prior to the deintegration of experiment-tray A0171 the solar cell module, recoved from the Shuttle's Cargo Bay, was photodocumented using component number E01. After the experiment tray was removed from LDEF, the entire tray surface was photodocumented using component number E00.

The M&D SIG survey identified a total of 327 features on the A08 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the experimental-tray surfaces. Two hundred and twenty of these were <0.5 mm but were not separated as to location on the tray. Of the remaining 90 impacts, 77 impacts were located on the experimental-tray surface these, 46 of the impacts were <0.5 mm in diameter (31 were photodocumented as they were considered to be of interest, ten of which were located on the recovered solar cell module), 25 were between 0.5 mm and 1.0 mm in diameter, five were between 1.0 mm and 1.5 mm in diameter, and one was between 1.5 mm and 2.0 mm in diameter. Of the six impacts on the experiment-tray flanges and walls, one was <0.5 mm in diameter and was photodocumented, and the other five were between 0.5 mm and 1.0 mm in diameter. On the experiment-tray clamps, 20 of the 24 impacts identified were <0.5 mm in diameter (three of these were photodocumented), and four were between 0.5 mm and 1.0 mm in diameter.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	20			287*
>0.5 mm	4	5	31	40
TOTALS	24			327

* - The locations of the "Too Smalls" were not documented.

The largest impact features identified on tray A08 were (1) an ~2.0 mm diameter crater located on a solar cell, (2) an ~1.5 mm diameter crater located in the aluminum sample holder, (3) an ~0.8 mm diameter crater located on the experiment-tray flange, and (4) an ~1.0 mm crater located on experiment-tray clamp C01.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 22, 1990 while the experiment-tray was mounted on the spacecraft. This inspection identified five features which might be destroyed by attachment of the experiment-tray cover and two features which would be destroyed by emplacement in the experiment-tray rotator. These latter impact features were estimated to be ~0.5 mm in diameter. These features were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in four locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges. One feature each was identified on clamps C01, C02, C03, C04, and C07; the latter feature was located in the paint sample attached to the clamp. Three features were identified on clamp C08.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations or spallation features on the front or back of the 0.0625" (1.6 mm) thick experiment-tray flanges. However, there was an ejecta spray pattern located on the back of the lower tray flange, ~450 cm from the (0,0) corner of the tray. The impact was located on LDEF aluminum structural longeron.

DOCUMENTATION:

The detailed examination and photodocumentation of tray A08 was conducted on February 28, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #1. The bolts, clamps and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale. The recovered solar cell module was scanned using M&D SIG System #1, and the coordinates for features were measured with a metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	67	958	67	-17
Center	626	957	625	-17
Far Right	1185	958	1184	-18

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC010001.A08	RC010001.A08	48	1		0.9	Al	
LC020001.A08	RC020001.A08	20	28		0.8	Al	
LC030001.A08	RC030001.A08	126	11		0.4	Al	*1*
LC070001.A08	RC070001.A08	87	30		0.5, 1.0	Al	*2,3,b*
LC080001.A08	RC080001.A08	22	46		0.7	Al	
LC080002.A08	RC080002.A08	17	75		0.5	Al	
LC080003.A08	RC080003.A08	16	88		0.4 x 0.5	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.A08	RE000001.A08	163	965		0.7	Al	*4*
LE000002.A08	RE000002.A08	360	984		0.6	Al	*4*
LE000004.A08	RE000004.A08	406	937		0.3	Al	*4*
LE000014.A08	RE000014.A08	6	506		0.6	Al	*5,d,f*
LE000054.A08	RE000054.A08	917	-29		0.8	Al	*6*
LE000058.A08	RE000058.A08	174	-27		0.6	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000003.A08	RE000003.A08	235	912		0.2	Kapton	
LE000005.A08	RE000005.A08	390	813		0.7	Al	
LE000006.A08	RE000006.A08	432	868		0.6	Al	*7*
LE000007.A08	RE000007.A08	511	822		0.4	Composite	*8*
LE000008.A08	RE000008.A08	591	865		0.1, 0.4	Composite	*2,9,b,k*
LE000009.A08	RE000009.A08	959	916		0.5 x 1.0	SC	*m*
LE000010.A08	RE000010.A08	975	870		0.8 x 1.0	SC Grid Wire	*m*
LE000011.A08	RE000011.A08	1084	902		0.1 x 0.2, 0.6	SC	*2,10,b,c,k*
LE000012.A08	RE000012.A08	8	764		0.6	Al	
LE000013.A08	RE000013.A08	14	568		0.7	Al	
LE000015.A08	RE000015.A08	289	711		1.0	Al	*11*
LE000016.A08	RE000016.A08	81	600		0.6	Al	
LE000017.A08	RE000017.A08	92	617		0.3	ATS	
LE000018.A08	RE000018.A08	153	576		0.3	T/A	
LE000019.A08	RE000019.A08	344	525		0.4	Cu	*12*
LE000020.A08	RE000020.A08	448	560		0.5	SC	*m*
LE000021.A08	RE000021.A08	578	672		0.1, 0.6 x 1.0	Composite	*2,13,b*
LE000022.A08	RE000022.A08	842	566		1.2	Al	
LE000023.A08	RE000023.A08	835	717		0.8	Al	
LE000024.A08	RE000024.A08	1007	714		0.5	Al	*14*
LE000025.A08	RE000025.A08	1023	761		0.5	Al	
LE000026.A08	RE000026.A08	1178	683		0.5, 1.0	SC	*15,m*
LE000027.A08	RE000027.A08	1197	672		0.7, 1.8	SC	*15,16,m*
LE000028.A08	RE000028.A08	1203	683		0.5, 1.3	SC	*15,m*
LE000029.A08	RE000029.A08	117	437		0.7	Al	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000030.A08	RE000030.A08	175	408		0.7	Al	
LE000031.A08	RE000031.A08	143	262		0.4	SC	
LE000032.A08	RE000032.A08	301	266		0.5	Al	
LE000033.A08	RE000033.A08	254	216		0.6	Al	
LE000034.A08	RE000034.A08	259	207		0.7	Al	
LE000035.A08	RE000035.A08	339	217		1.0	Al	
LE000036.A08	RE000036.A08	410	458		0.9	Al	
LE000037.A08	RE000037.A08	637	438		0.8	Al	
LE000038.A08	RE000038.A08	832	415		0.5	Al	
LE000039.A08	RE000039.A08	642	381		0.3	Elastomer	
LE000040.A08	RE000040.A08	726	328		0.5	Elastomer	
LE000041.A08	RE000041.A08	766	259		0.3	Elastomer	
LE000042.A08	RE000042.A08	827	231		0.7	Al	
AE000042.A08	BE000042.A08	827	231		0.7	Al	
LE000043.A08	RE000043.A08	890	418		0.2	Al	*17,18,d*
LE000044.A08	RE000044.A08	867	379		1.3	Al	
LE000045.A08	RE000045.A08	942	382		0.3	Nb	
LE000046.A08	RE000046.A08	1020	336		0.4	Al	*19,c*
LE000047.A08	RE000047.A08	1049	368		1.2	Al	
LE000048.A08	RE000048.A08	1024	261		0.5	Al	
LE000049.A08	RE000049.A08	1159	380		0.6, 3.2	Ag on Ti	*2,b*
LE000050.A08	RE000050.A08	1202	92		0.3	Ag alloy	
LE000051.A08	RE000051.A08	1181	161		0.6	Al	
LE000052.A08	RE000052.A08	1044	71		1.5	Al	*6*
LE000053.A08	RE000053.A08	934	112		0.7	Al	
LE000055.A08	RE000055.A08	390	57		0.2, 1.8	SC	*15,m*
LE000056.A08	RE000056.A08	291	56		2.0, 5.0	SC	*15,m*
LE000057.A08	RE000057.A08	257	126		ND	SC Grid Wire	*20*
LE010001.A08	RE010001.A08	3	19		0.1	Kapton and SC	*21*
LE010002.A08	RE010002.A08	8	72		0.1	Cu Interconnect	*21*
LE010003.A08	RE010003.A08	7	100		0.1	Kapton and SC	*21*
LE010004.A08	RE010004.A08	50	40		0.3 x 0.5	Kapton and SC	*21,m*
AE010004.A08	BE010004.A08	50	40		0.3 x 0.5	Kapton and SC	*21,22,m*
LE010005.A08	RE010005.A08	56	122		0.1 x 0.2	Kapton and SC	*21,b*
LE010006.A08	RE010006.A08	64	98		0.1	Kapton and SC	*21,b*
LE010007.A08	RE010007.A08	65	88		0.2	Kapton and SC	*21,b,m*
AE010007.A08	BE010007.A08	65	88		0.2	Kapton and SC	*21,22,b,m*
LE010008.A08	RE010008.A08	68	38		0.3	Kapton and SC	*21*
LE010009.A08	RE010009.A08	71	39		0.1	Kapton and SC	*21,a,b*
LE010010.A08	RE010010.A08	30	41		ND	SC cover glass	*23,m*
LE010011.A08	RE010011.A08	74	12		ND	SC cover glass	*24,m*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined
SC - Solar Cell
ATS - Aluminized Teflon on S-Glass substrate
T/A - Teflon on aluminum substrate

1 - Impact located on edge of clamp.

2 - Diameter after comma is diameter of spallation.
3 - Impact into paint sample attached to clamp.
4 - Image taken at 45° below normal to crater.
5 - Image taken at 45° above normal to crater.
6 - Wrong coordinates (X = 500, Y = 438) input into image file.
7 - Wrong coordinates (X = 390, Y = 813) input into image file.
8 - Wrong diameter (D = 0.71 mm) input into image file.
9 - Green colored material in bottom of crater.
10 - Impact delaminated grid wire from solar cell; red colored material in bottom of crater.
11 - Wrong coordinates (X = 195, Y = 736) input into image file.
12 - Impact on Kapton-coated copper interconnect for solar cell module.
13 - Impact into graphite composite with ash-like surface.
14 - Wrong coordinates (X = 1023, Y = 761) input into image file.
15 - Diameter after comma is diameter of fracture zone around crater.
16 - Impact induced a 70.0 mm long crack in the solar cell cover glass.
17 - Wrong coordinates (X = 651, Y = 180) input into image file.
18 - Impact into edge of sample holder; ejecta spray onto copper sample.
19 - Impact into Chemglaze Z-853 painted aluminum caused paint to delaminate from aluminum.
20 - Not impact related: solder spray (possibly due to electrical discharge), image taken at Principal Investigator's request.
21 - Impact into space exposed (back side) surface of recovered solar cell module.
22 - Image of unexposed (front side) surface of recovered solar cell module showing impact induced cracking of cover glass.
23 - Impact into front side surface of recovered solar cell module, into cover glass.
24 - May not be an impact related fracture zone.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-89-4422
On-Orbit - S32-76-27
Pre-Deintegration - KSC-390C-1031.03, KSC-390C-1031.04, KSC-390C-1031.12
Post Deintegration - KSC-390C-1411.03, KSC-390C-1411.04, KSC-390C-1412.07
M&D SIG Photos - None

ARCHIVED MATERIALS:

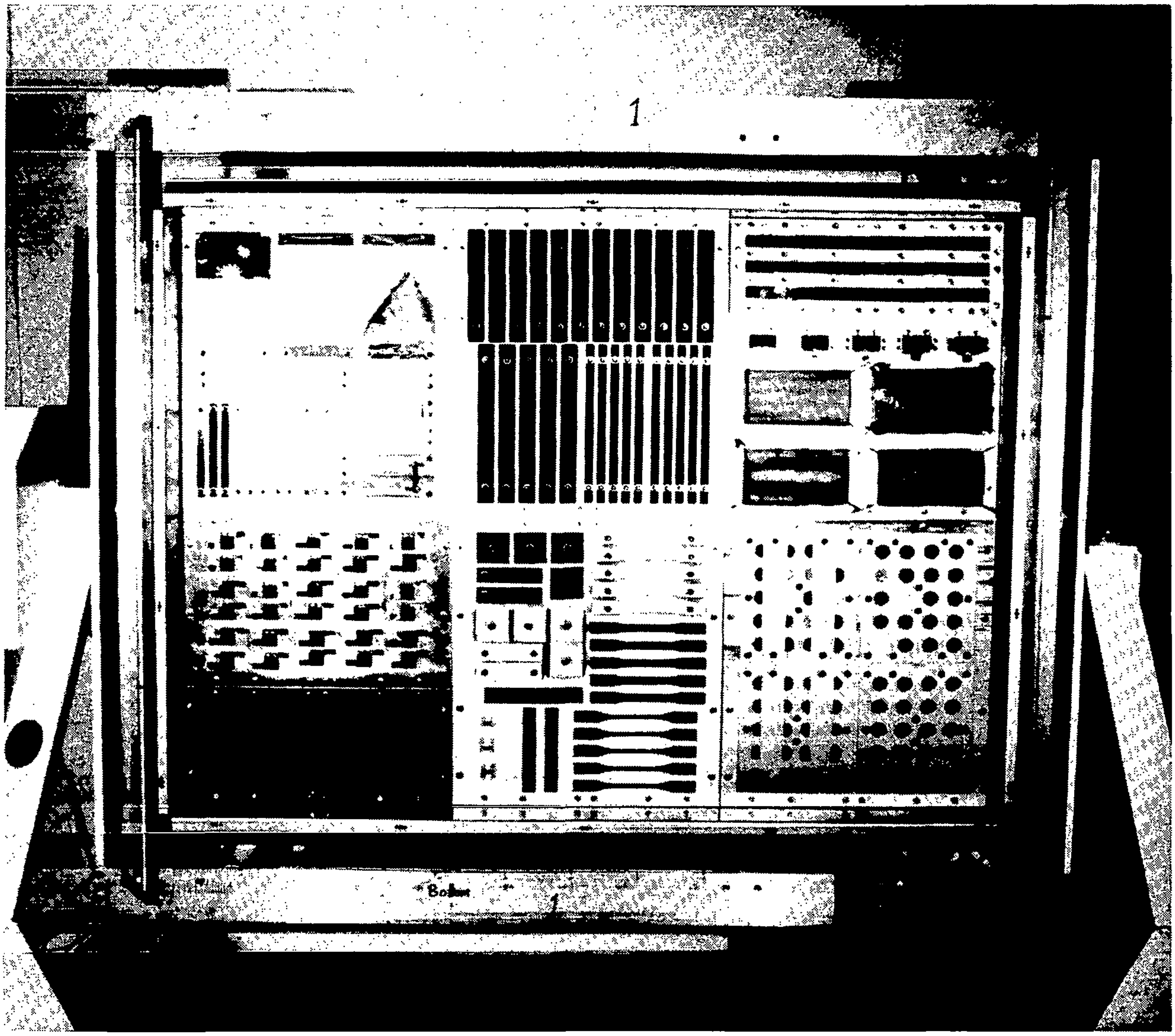
Clamps - A08C01, A08C03, A08C07, and A08C08

ACCOMPANYING FIGURES:

Figure A08-1 - This post-deintegration view shows the front of the entire A08 experiment tray.

Figure A08-2 - This is a close-up of the sub-tray in the lower left of tray A08, showing an impact feature on a solar cell. This view measures approximately 13 cm across.

Figure A08-3. This is a close-up on an impact into a solar cell, showing accompanying shattering, and measures approximately 3 cm across.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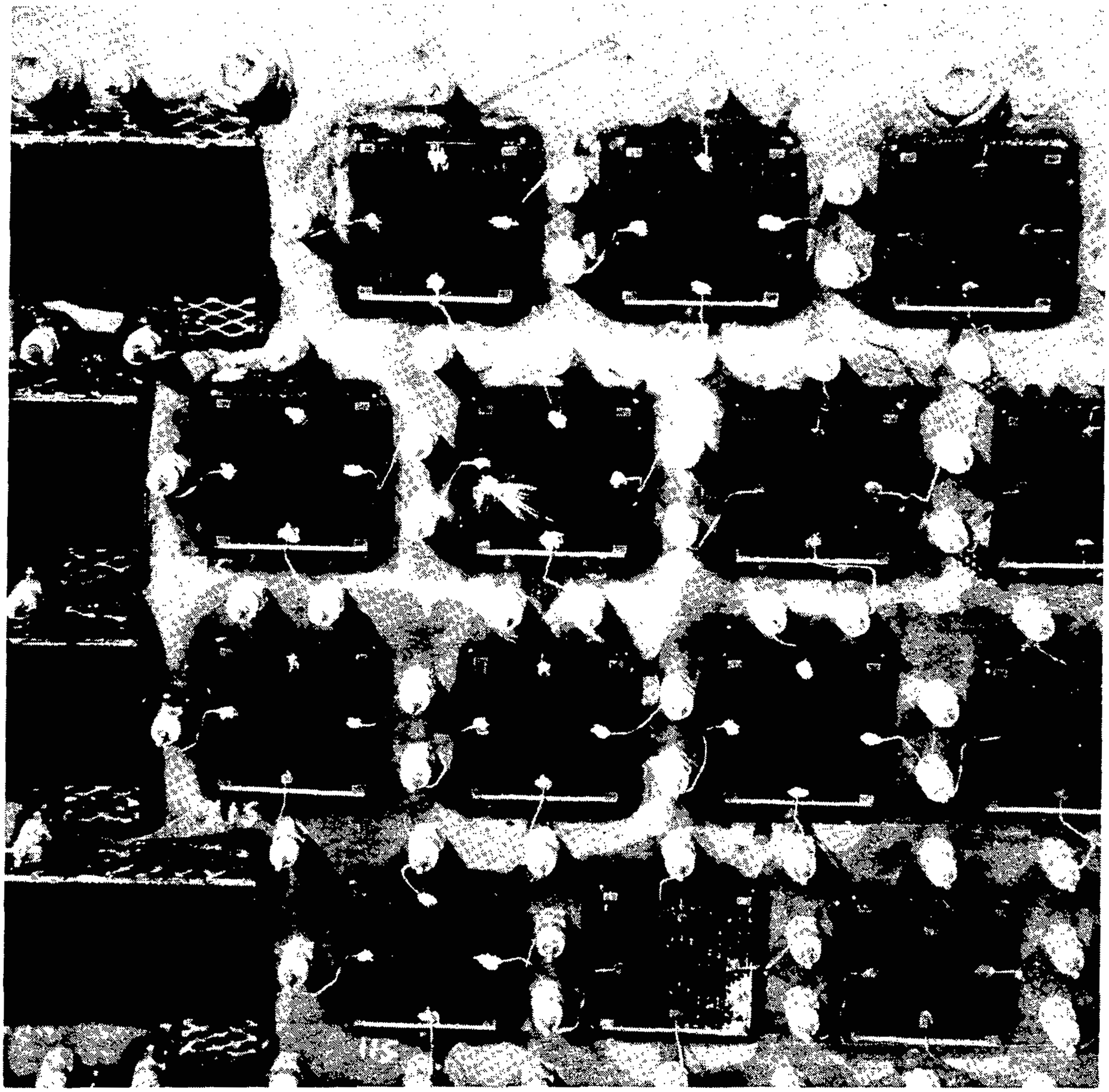


LDEF LOCATION: A09
EXPERIMENT IDENTIFICATION: S0069
EXPERIMENT TITLE: THERMAL CONTROL SURFACES EXPERIMENT
PRINCIPAL INVESTIGATOR: D. WILKES
NASA MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

SUMMARY OF OBSERVATIONS

Bay A09 housed the active 12"-deep (30.5 cm) "carousel" experiment. The S0069 experiment was designed to measure certain physical properties of 25 "active" spacecraft thermal control samples in an environment that approximates their normal use. The active samples were contained in calorimeter assemblies and were mounted along with the passive samples on the rotating carousel. In addition, three radiometers were also mounted on the carousel. The carousel was rotated 180° from the protected environment into space exposure for approximately 23.5 hours for every Earth day. The rest of the exposed surface of this tray was a silver-backed teflon thermal control blanket material, which directly covered either fiberglass or aluminum. In one notable place, a large impact delaminated a considerable amount of the teflon blanket, exposing the silver backing to oxygen erosion. This feature stands out on photos of this tray as a large black blemish in the lower right.

The M&D SIG survey identified a total of 582 features on the A09 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the experimental tray surface including the rotating carousel. Of these, 543 features from all surfaces were found to be less than the 0.5 mm photodocumentation threshold. Of the 543 features too small to photodocument, 537 were located on the experimental tray surface and six were located on the clamps, bolts and shims. Forty-three features were photodocumented on the aluminum or fiberglass experimental surfaces covered by the teflon blanket and ranged in size from 0.4 mm to 2.5 mm in diameter; only one impact was documented into one the radiometers' coverglass located on the rotating carousel. Three features were documented on the experiment tray-flanges and ranged in size from 0.6 mm to 1.3 mm in diameter and eleven features were documented on the experimental-tray bolts and clamps which ranged in size from 0.3 mm to 0.8 mm in diameter. All features into aluminum exhibited characteristics typical of craters formed in aluminum during laboratory hypervelocity impact experiments.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	6			543*
>0.5 mm	5	3	31	39
TOTALS	11			582

* - The locations of the "Too Smalls" were not documented.

The largest impact feature identified on tray A09 was a circular impact ~2.5 mm in diameter; there were six other impact features with diameters of ~1 mm or more.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft and identified six features that might be damaged by the placement of the experiment-tray cover

and five additional features that could be damaged or destroyed by the placement of the experiment-tray within the experiment-tray stand. The latter impact features were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in three locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges or spallation features on the 0.125" (3.2 mm) thick experiment-tray flanges or backside.

DOCUMENTATION:

Examination and photodocumentation of tray A09 was conducted on March 1, 1990 in the vertical position utilizing M&D SIG System and Coordinate Registration System #2. The bolts, clamps, and shims associated with this tray were scanned with M&D SIG System #3 and coordinates were measured using a small metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	67	933	61	-40
Middle	625	932	617	-42
Far Right	1183	932	1177	-43

NOTE: zero is 15 mm above normal.

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC010001.A09	RC010001.A09	30	19		0.8	Al	
LC020001.A09	RC020001.A09	21	38		0.4	Al	
LC020002.A09	RC020002.A09	107	1		0.7	Al	
LC040001.A09	RC040001.A09	16	21		0.3	Al	
LC040002.A09	RC040002.A09	23	12		0.3	Al	
LC050001.A09	RC050001.A09	46	35		0.5	Al	
LC050002.A09	RC050002.A09	49	1		0.7	Al	
LC060001.A09	RC060001.A09	69	40		0.4	Al	
LC060002.A09	RC060002.A09	114	48		0.4	Al	
LC070001.A09	RC070001.A09	9	48		0.8	Al	
LC080001.A09	RC080001.A09	23	114		0.4	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.A09	RE000001.A09	1	830		0.6	Al	
LE000046.A09	RE000046.A09	877	-74		1.3	Al	
LE000021.A09	RE000021.A09	1088	963		0.8	Al	w

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.A09	RE000002.A09	45	839		0.6	Ag/Teflon	
LE000003.A09	RE000003.A09	122	816		0.6	Ag/Teflon	*j*
LE000004.A09	RE000004.A09	144	809		0.8	Ag/Teflon	
LE000005.A09	RE000005.A09	166	765		1.0	Ag/Teflon	
LE000006.A09	RE000006.A09	194	833		0.5	Ag/Teflon	*j*
LE000007.A09	RE000007.A09	171	873		0.7	Ag/Teflon	*w*
LE000008.A09	RE000008.A09	226	784		0.7	Ag/Teflon	*w*
LE000009.A09	RE000009.A09	301	885		0.5	Ag/Teflon	*w*
LE000010.A09	RE000010.A09	342	865		1.1	Ag/Teflon	*w*
LE000011.A09	RE000011.A09	379	835		0.7	Ag/Teflon	
LE000012.A09	RE000012.A09	453	855		0.7	Ag/Teflon	
LE000013.A09	RE000013.A09	477	863		0.6	Ag/Teflon	
LE000014.A09	RE000014.A09	589	885		0.5	Ag/Teflon	
LE000015.A09	RE000015.A09	628	868		1.5	Ag/Teflon	
LE000016.A09	RE000016.A09	696	769		0.7	Ag/Teflon	*1*
LE000017.A09	RE000017.A09	709	882		0.4	Ag/Teflon	
LE000018.A09	RE000018.A09	849	830		ND	Ag/Teflon	*2*
LE000019.A09	RE000019.A09	883	886		1.1	Ag/Teflon	
LE000020.A09	RE000020.A09	1059	853		0.4	Ag/Teflon	
LE000022.A09	RE000022.A09	1190	720		0.5	Ag/Teflon	
LE000023.A09	RE000023.A09	52	694		0.8	Ag/Teflon	
LE000024.A09	RE000024.A09	83	625		0.5	Ag/Teflon	
LE000025.A09	RE000025.A09	92	625		0.5	Ag/Teflon	
LE000026.A09	RE000026.A09	123	617		0.8	Ag/Teflon	*b*
LE000027.A09	RE000027.A09	140	630		0.5	Ag/Teflon	*b*
LE000028.A09	RE000028.A09	153	650		0.8	Ag/Teflon	
LE000029.A09	RE000029.A09	153	652		1.0	Ag/Teflon	
LE000030.A09	RE000030.A09	264	718		1.3	Ag/Teflon	
LE000031.A09	RE000031.A09	307	702		0.6	Ag/Teflon	
LE000032.A09	RE000032.A09	626	652		0.5	Ag/Teflon	*j*
LE000033.A09	RE000033.A09	695	712		ND	Ag/Teflon	
LE000034.A09	RE000034.A09	811	696		0.7	Ag/Teflon	
LE000035.A09	RE000035.A09	1164	734		0.4	Ag/Teflon	
LE000036.A09	RE000036.A09	1144	708		ND	Fiberglass	
LE000037.A09	RE000037.A09	1299	633		ND	Fiberglass	
LE000038.A09	RE000038.A09	1162	525		0.3	Ag/Teflon	
LE000039.A09	RE000039.A09	1186	482		ND	Ag/Teflon	
LE000040.A09	RE000040.A09	1151	337		0.3	Fiberglass	
LE000041.A09	RE000041.A09	1096	270		ND	Fiberglass	
LE000042.A09	RE000042.A09	1043	248		0.3	Ag/Teflon	
LE000043.A09	RE000043.A09	861	379		0.5	Ag/Teflon	
LE000044.A09	RE000044.A09	620	220		0.3	Radiometer CG	
LE000045.A09	RE000045.A09	457	52		2.5	Ag/Teflon	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not determined

1 - Wrong coordinates (X = 616, Y = 782) input into image file.
2 - Wrong coordinates (X = 838, Y = 735) input into image file.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-348C-209/3
On-Orbit - S32-76-05
Pre-Deintegration - KSC-390C-1030.12, KSC-390C-1031.01
Post Deintegration
M&D SIG Photos - S90-43379, S90-43380, and S90-43381

ARCHIVED MATERIALS:

Clamps - A09C01, A09C02, A09C05, and A09C06

LDEF LOCATION: A10
EXPERIMENT IDENTIFICATION: A0178
EXPERIMENT TITLE: A HIGH-RESOLUTION STUDY OF ULTRA-HEAVY COSMIC-RAY NUCLEI
PRINCIPAL INVESTIGATOR: D. O'SULLIVAN
DUBLIN INSTITUTE FOR ADVANCED STUDIES
DUBLIN, IRELAND

SUMMARY OF OBSERVATIONS

Bay A10 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46" long (~116.8 cm), 10" (25.4 cm) in diameter, 6063-T6 aluminum cylinders (1.9 mm thick) which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with an ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (space facing) of FEP teflon (~120 μm thick) backed with a thin layer of vapor-deposited silver/inconel (~200 to 300 Å thick), which in turn was backed by DC1200 primer and Chemglaze Z306 black conductive paint (~80 to 100 lm thick). The blankets were attached to a 40-5052 aluminum support frame by ~1" x 2" (~2.5 x 5.1 cm) strips of velcro.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of the resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted teflon material. Commonly, the teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. Many possessed several sharp, distinct rings, while other exhibited a more continuous halo phenomenon where the changes from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impact craters into aluminum.

The M&D SIG survey identified a total of 700 features on the A10 experiment tray including the experiment-tray clamps and flanges, as well as the thermal insulation blanket. Of these, 584 were found on the thermal blanket, all but a few representing penetration through the blanket. Four hundred and ninety seven features from the blanket were below the 0.3 mm diameter photodocumentation threshold (five "Too Smalls" were imaged because they were considered of interest), 84 features were between 0.3 mm and 1.0 mm in diameter, and three features were photodocumented that were between 1.0 mm and 1.5 mm in diameter. Eighty one features were found on the tray flanges, 69 of which were <0.5 mm in diameter, eight of which were between 0.5 mm and 1.0 mm in diameter, and three that were between 1.0 mm and 1.5 mm in diameter. The remaining 35 features were located while scanning the associated bolts, clamps and shims for tray A10. Thirty one features on the clamps (C01-C08) were <0.5 mm in diameter, three were between 0.5 mm and 1.0 mm in diameter, and one feature on clamp C06 that was ~2.8 mm in diameter.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			497	497
>0.3 mm			87	87
<0.5 mm	31	69		100
>0.5 mm	4	12		16
TOTALS	35	81	584	700

The largest impact features identified on tray A10 were (1) an ~1.1 mm penetration hole through the thermal blanket, (2) an ~1.5 mm crater in the experiment-tray flange, and (3) an ~2.8 mm impact crater on clamp C06. The largest non-circular feature on this tray was an elliptical penetration hole that measured ~0.6 x 0.8 mm along the semi-minor and -major axes, respectively.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft and identified seven features that might be damaged by the emplacement of the experiment-tray cover and four additional features that could be damaged or destroyed by the placement of the experiment-tray within the experiment-tray stand. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in three locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges. One feature each was identified on clamps C02, C05, and C06. The feature on clamp C06 was estimated to be between ~2 mm and ~3 mm in diameter; several photographs were taken of this feature by the M&D SIG A-Team (Roll 59, Frames 1-3).

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick aluminum experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of tray A10 was conducted on March 21 and 22, 1990 in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #2. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale.

At least two impacts into the thermal blanket penetrated the velcro that was attached to the backside of the blanket and the aluminum frame supporting the blanket above the experimental canisters; craters were visible in the aluminum frame beneath both of these features. Both pieces of velcro (*i.e.*, the hook and the loop portions) from below LE000079.A10 and AE000079.A10 were removed when the blanket was trisected, removed, and packaged for shipment in order to maintain their relationship in the hope of recovering projectile materials. This particular third of the thermal blanket from tray A10 was shipped to JSC for curation.

Bolt-Hole Registration (mm)

	TOP X	TOP Y	BOTTOM X	BOTTOM Y
Far Left	59	947	55	-28
Center	617	949	614	-25
Far Right	1176	952	1180	-24

Fiducial Mark Locations (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Left	227	904	230	24
Middle	624	900	596	24
Right	1010	895	1004	25

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC020001.A10	RC020001.A10	78	28		0.4	Al	*1,b*
LC050001.A10	RC050001.A10	110	3		0.9	Al	
LC060001.A10	RC060001.A10	90	35		2.8	Al	*d*
LC080001.A10	RC080001.A10	20	115		0.5	Al	*2*

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.A10	RE000001.A10	535	981		1.2	Al	
LE000002.A10	RE000002.A10	1002	940		0.5	Al	
LE000003.A10	RE000003.A10	800	974		1.3	Al	
LE000004.A10	RE000004.A10	1257	842		1.0	Al	
LE000005.A10	RE000005.A10	1267	690		0.7	Al	
LE000032.A10	RE000032.A10	1257	336		0.5	Al	
LE000098.A10	RE000098.A10	1262	177		0.6	Al	
LE000099.A10	RE000099.A10	901	-52		1.5	Al	
LE000100.A10	RE000100.A10	569	-7		0.7	Al	
LE000101.A10	RE000101.A10	115	-4	5	0.6	Al	*15,f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000006.A10	RE000006.A10	29	894		0.5	TB	
LE000007.A10	RE000007.A10	129	844		0.3	TB	
LE000008.A10	RE000008.A10	95	798		0.7	TB	
LE000009.A10	RE000009.A10	244	918		0.4	TB	
LE000010.A10	RE000010.A10	299	883		0.2	TB	
LE000011.A10	RE000011.A10	326	896		0.4	TB	
LE000012.A10	RE000012.A10	323	888		0.3	TB	
LE000013.A10	RE000013.A10	387	866		0.4	TB	
LE000014.A10	RE000014.A10	341	855		0.3	TB	
LE000015.A10	RE000015.A10	419	893		0.3	TB	*3*
LE000016.A10	RE000016.A10	448	782		0.5	TB	
LE000017.A10	RE000017.A10	458	791		0.2	TB	
LE000018.A10	RE000018.A10	516	823		0.3	TB	
LE000019.A10	RE000019.A10	535	811		0.6	TB	
LE000020.A10	RE000020.A10	611	793		0.3	TB	
LE000021.A10	RE000021.A10	616	876		0.3	TB	
LE000022.A10	RE000022.A10	669	817		0.4	TB	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000023.A10	RE000023.A10	728	810		0.5 x 0.6	TB	*4*
LE000024.A10	RE000024.A10	741	813		0.3	TB	
LE000025.A10	RE000025.A10	795	897		0.3	TB	
LE000026.A10	RE000026.A10	806	857		0.2	TB	
LE000027.A10	RE000027.A10	878	890		0.3	TB	
LE000028.A10	RE000028.A10	885	809		0.5	TB	
AE000028.A10	BE000028.A10	885	809		0.5	TB	
LE000029.A10	RE000029.A10	966	822		0.8	TB	
LE000030.A10	RE000030.A10	1026	818		0.6 x 0.8	TB	*4*
LE000031.A10	RE000031.A10	1185	856		0.8	TB	*5*
LE000033.A10	RE000033.A10	162	720		0.6	TB	
LE000034.A10	RE000034.A10	41	663		0.5	TB	*5*
LE000035.A10	RE000035.A10	12	609		0.6	TB	
LE000036.A10	RE000036.A10	152	654		0.4	TB	
LE000037.A10	RE000037.A10	371	654		0.4	TB	
LE000038.A10	RE000038.A10	442	690		0.6	TB	
LE000039.A10	RE000039.A10	518	688		0.4	TB	
LE000040.A10	RE000040.A10	612	691		0.3	TB	
LE000041.A10	RE000041.A10	667	653		0.4	TB	
LE000042.A10	RE000042.A10	729	575		0.4	TB	
LE000043.A10	RE000043.A10	733	569		0.4	TB	
LE000044.A10	RE000044.A10	880	699		0.7	TB	
LE000045.A10	RE000045.A10	931	655		0.5	TB	
LE000046.A10	RE000046.A10	890	556		0.5	TB	
LE000047.A10	RE000047.A10	915	551		0.6	TB	
LE000048.A10	RE000048.A10	1025	540		0.6	TB	
LE000049.A10	RE000049.A10	1126	661		1.0	TB	
LE000050.A10	RE000050.A10	1125	554		0.5	TB	
LE000051.A10	RE000051.A10	1210	563		0.4	TB	
LE000052.A10	RE000052.A10	1187	347		0.4	TB	
LE000053.A10	RE000053.A10	1060	258		0.5	TB	*6*
LE000054.A10	RE000054.A10	1129	286		0.5	TB	
LE000055.A10	RE000055.A10	1062	341		0.5	TB	
LE000056.A10	RE000056.A10	989	239		0.7	TB	
LE000057.A10	RE000057.A10	880	438		0.5 x 0.6	TB	*4*
LE000058.A10	RE000058.A10	839	236		0.4	TB	
LE000059.A10	RE000059.A10	784	292		0.5	TB	*5*
LE000060.A10	RE000060.A10	795	469		0.6	TB	
LE000061.A10	RE000061.A10	756	380		0.5	TB	
LE000061.A10	RE000061.A10	756	380		0.5	TB	
LE000062.A10	RE000062.A10	713	431		0.5	TB	
LE000063.A10	RE000063.A10	619	480		0.5	TB	*7*
LE000064.A10	RE000064.A10	619	286		0.5	TB	
LE000065.A10	RE000065.A10	532	238		0.6	TB	
LE000066.A10	RE000066.A10	526	377		0.5	TB	
LE000067.A10	RE000067.A10	544	393		0.5	TB	
LE000068.A10	RE000068.A10	580	475		0.5	TB	
LE000069.A10	RE000069.A10	430	370		0.5	TB	*8*
LE000070.A10	RE000070.A10	432	346		0.6	TB	*8*
LE000071.A10	RE000071.A10	432	346		0.6	TB	*8,9,10*
LE000072.A10	RE000072.A10	336	283		0.4	TB	
LE000073.A10	RE000073.A10	258	461		0.4	TB	*11*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000074.A10	RE000074.A10	276	491		0.4	TB	
LE000075.A10	RE000075.A10	132	448		0.4 x 0.5	TB	*4*
LE000076.A10	RE000076.A10	103	427		0.5	TB	*3*
LE000077.A10	RE000077.A10	59	387		0.5 x 0.6	TB	*4,16*
LE000078.A10	RE000078.A10	235	336		0.5 x 0.5	TB	*4,16*
LE000079.A10	RE000079.A10	239	306		0.8	TB	*8,12*
AE000079.A10	BE000079.A10	239	306		0.8	TB	*8,12,13*
LE000080.A10	RE000080.A10	88	240		0.5	TB	
LE000081.A10	RE000081.A10	541	535		1.1	TB	
LE000082.A10	RE000082.A10	69	114		0.8	TB	
LE000083.A10	RE000083.A10	4	32		0.4	TB	
LE000084.A10	RE000084.A10	153	136		0.6	TB	*3*
LE000085.A10	RE000085.A10	247	97		0.5	TB	
LE000086.A10	RE000086.A10	282	14		0.6	TB	
LE000087.A10	RE000087.A10	501	45		0.6	TB	
LE000088.A10	RE000088.A10	549	195		0.5	TB	
LE000089.A10	RE000089.A10	591	181		0.8	TB	
LE000090.A10	RE000090.A10	578	18		0.5	TB	
LE000091.A10	RE000091.A10	694	37		0.8	TB	
LE000092.A10	RE000092.A10	707	130		0.5	TB	
LE000093.A10	RE000093.A10	781	205		1.0	TB	
LE000094.A10	RE000094.A10	933	43		0.5	TB	
LE000095.A10	RE000095.A10	975	91		0.4	TB	
LE000096.A10	RE000096.A10	1047	70		0.9	TB	
LE000097.A10	RE000097.A10	1107	21		0.5	TB	*14*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

TB - Thermal Blanket (teflon, silver-inconel, binder, and paint).

1 - Impact into paint specimen on clamp.
2 - Experiment number S0109 input into image file, should have been A0178.
3 - Small rings/halos around penetration.
4 - Elliptical feature.
5 - No rings/halos.
6 - Wrong coordinates (X = 1129, Y = 286) input with file.
7 - Wrong magnification input into image file.
8 - Penetration through blanket into velcro.
9 - Additional image of previous feature number, should not have had separate feature number assigned.
10 - Wrong coordinates (X = 336, Y = 283) input with file.
11 - Wrong coordinates (X = 276, Y = 491) input with file.
12 - Crater below blanket penetration into support frame.
13 - Higher magnification view of same feature.
14 - Wrong diameter (0.58 mm) stored with image, should have been 0.48 mm.
15 - Image taken at 45^{o} below normal of crater.
16 - Two features visible within image.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 84-07214
On-Orbit - S32-78-079
Pre-Deintegration - KSC-390C-1028.12, KSC-390C-1029.01, KSC-390C-1029.10
Post Deintegration - KSC-390C-2208.02, KSC-390C-2208.12
M&D SIG Photos - S90-43523, S90-43524 - Left 1/3 of Thermal Blanket; front- and back views.
S90-43525, S90-43526 - Center 1/3 of Thermal Blanket; front- and back views.
S90-43527, S90-43528 - Right 1/3 of Thermal Blanket; front- and back views.

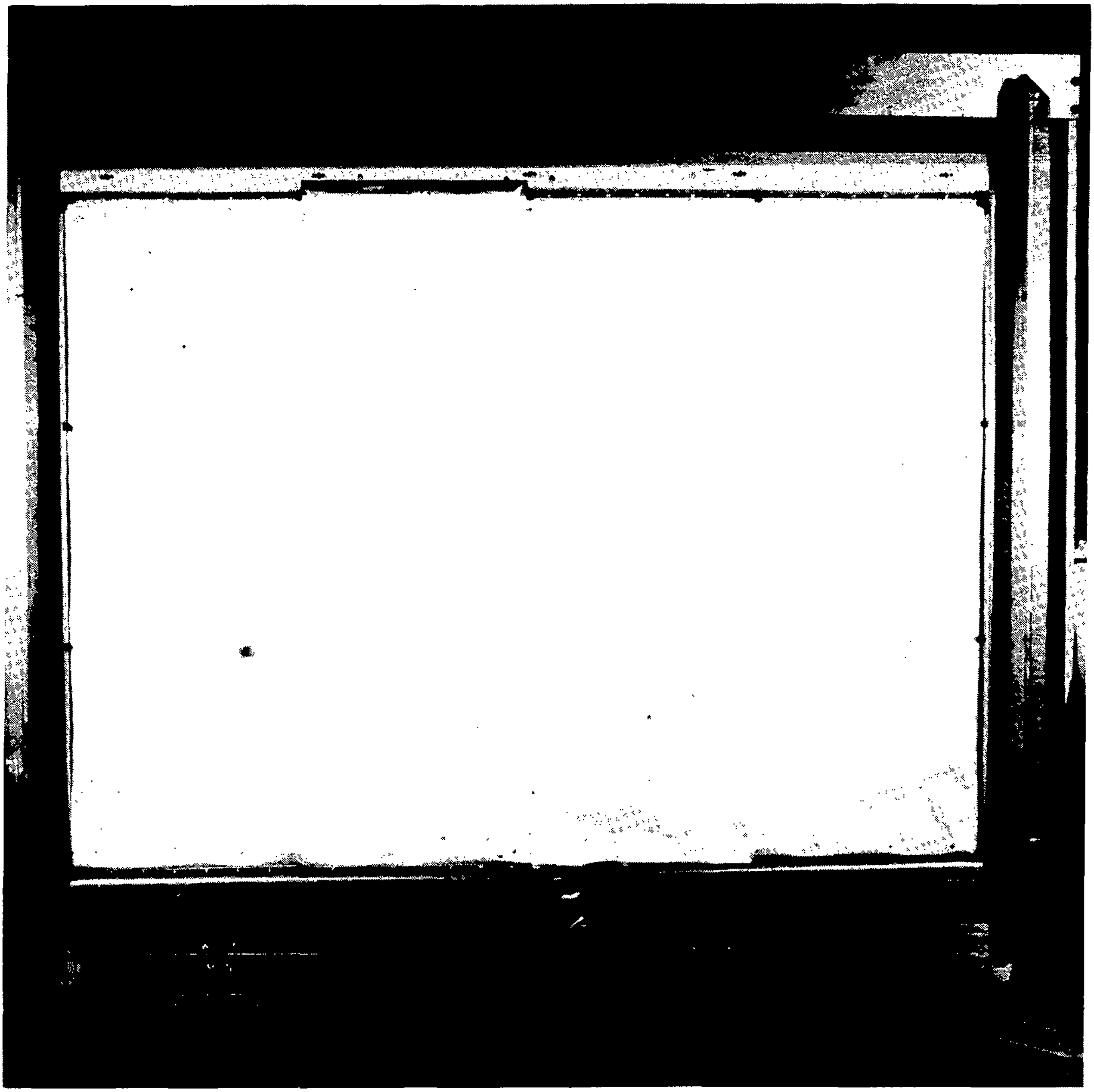
ARCHIVED MATERIALS:

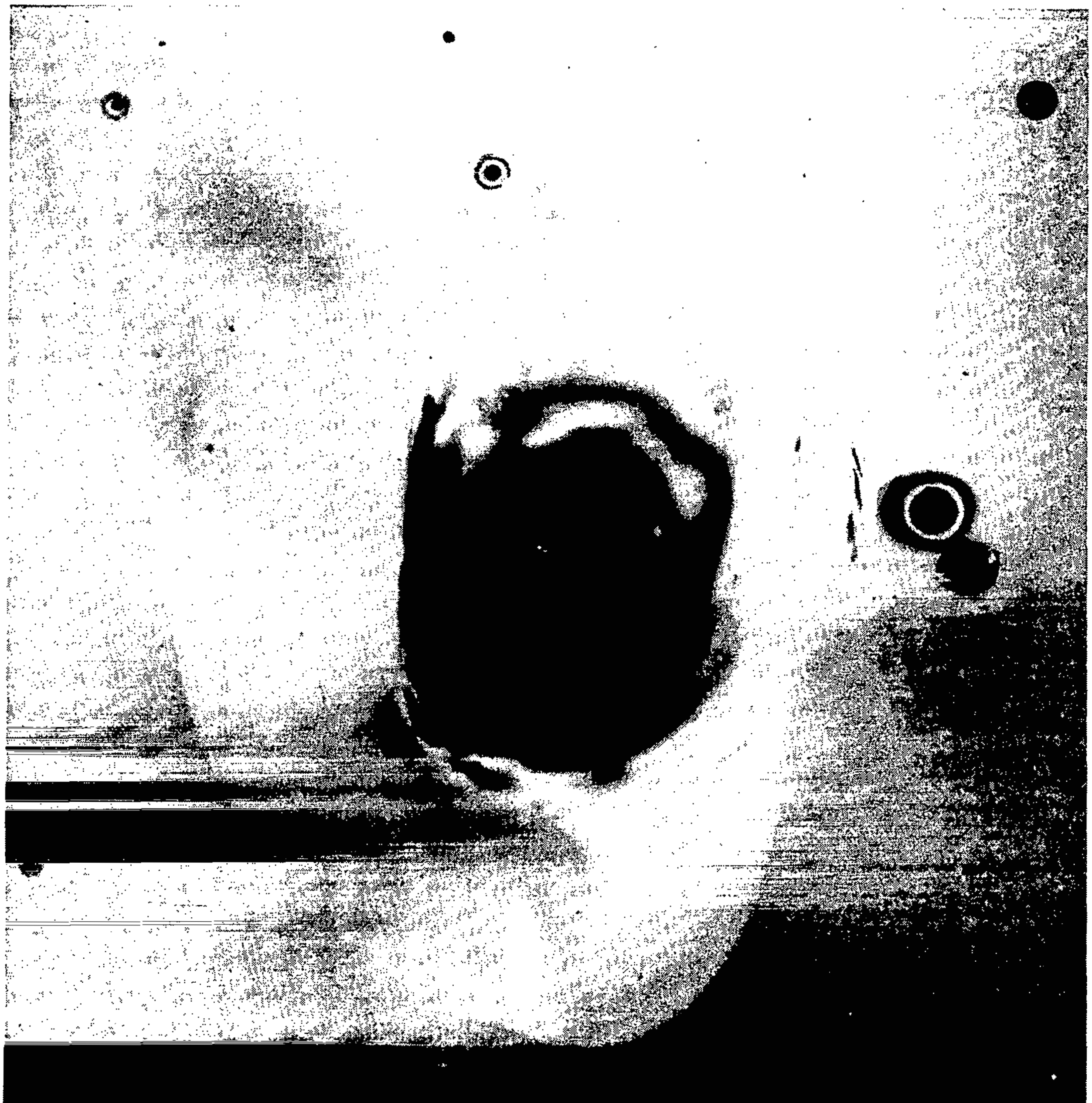
Clamps - A10C01, A10C02, A10C06, and A10C08
Clamp Bolts - A10S05B
Clamp Shims - A10H06
Thermal Blanket - (A10E00A) The U.S. third (minus the Materials SIG specimen) reside at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds (minus the Materials SIG grounding-strap specimen) is being archived at ESTEC in The Netherlands. Each blanket third was marked with two small crosses (see Fiducial Mark table above) for indexing and reconstruction purposes.

ACCOMPANYING FIGURES:

Figure A10-1 - This post-deintegration view shows the front of the entire A10 experiment thermal blanket. *Fleur-de-lis* patterns across the blanket are surface expressions of the velcro attachment points to the underlying aluminum frame. Many impact features are apparent across the blanket surface. The large impact feature in the lower left is also shown in Figure A10-2.

Figure A10-2. This is a view of large impact features on the A10 thermal blanket. Dark rings encircle many of the features. Some rings are incomplete. Rounded delamination areas surround most impact features shown here. View measures approximately 10 cm across.





LDEF LOCATION: A11
EXPERIMENT IDENTIFICATION: A0187-1
EXPERIMENT TITLE: CHEMISTRY OF MICROMETEOROIDS
PRINCIPAL INVESTIGATOR: F. HÖRZ
SN2 NASA JOHNSON SPACE CENTER
HOUSTON, TEXAS 77058

SUMMARY OF OBSERVATIONS

Tray A11 was a 3"-deep (7.6 cm), totally passive experiment-tray that was one of two experiment-trays composing the A0187-1 experiment; the other tray was located at position A03, was an active tray, and consisted predominantly of Au-collector surfaces. The six collector surfaces on A11 were 1100-T4 aluminum plates (each panel measuring 47 x 41 x 0.3 cm) rigidly mounted in frames to the experiment-tray.

The M&D SIG survey identified a total of 799 impact features on the experiment-tray surfaces which include the tray flanges, the clamps, the stainless steel bolts, and the six passive aluminum collector surfaces. Of these, 696 were <0.5 mm in diameter and were not imaged; the remaining 103 features ranged in diameter from 0.5 mm to 3.5 mm. Of these, 92 features were imaged by the M&D SIG, nine of which resided on the tray flanges; several other features on the tray flanges were not imaged because they were obstructed by the tray-stand clamping mechanism and could not be accessed. Twelve of the impacts were located on six of the eight clamps (C01, C03, C04, C05, C07, and C08; one impact each on clamps C01 and C03 were on the clamp edge), of which two were photo documented. All features were typical of craters produced in aluminum during laboratory hypervelocity impact test.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	10			696*
>0.5 mm	2		82	103
TOTALS	12			799

* - The locations of the "Too Smalls" were not documented.

The largest impact features identified on tray A11 were (1) two circular craters ~2.3 mm and ~3.5 mm in diameter located on the 1100-T4 aluminum collector surfaces, (2) a circular ~0.8 mm diameter feature located on the tray flange, and (3) a circular ~0.6 mm diameter feature located on clamp C07. The largest oblique feature measured ~0.8 x 0.9 mm along the semi-minor and -major axes, respectively.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft and identified 16 features that might be damaged by the emplacement of the experiment-tray cover and 6 additional features that could be damaged or destroyed by the placement of the experiment-tray within the experiment-tray stand. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in five locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges. One feature was identified on Clamp C03 near bolt C03B that might be damaged as a result of the tray-removal procedures (*i.e.*, by the socket wrench used to remove tray-clamp bolts). Two <0.5 mm features were found to reside on clamp edges (C01 and C03), while one was identified on the washer associated with bolt C01A.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick experiment-tray flanges. There were some apparent contamination (out-gassing) stains on the upper corners of the exterior experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of tray A11 was conducted on March 7, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #3. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	65	960	65	-15
Center	624	962	624	-14
Far Right	1183	962	1182	-14

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC070001.A11	RC070001.A11	74	46		0.5	Al	
LC080001.A11	RC080001.A11	48	21		0.6	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000034.A11	RE000034.A11	115	976		0.6	Al	
LE000035.A11	RE000035.A11	145	964		0.8	Al	
LE000036.A11	RE000036.A11	203	967		0.7	Al	
LE000037.A11	RE000037.A11	247	958		0.7	Al	
LE000087.A11	RE000087.A11	609	-3	2	0.5	Al	*f*
LE000088.A11	RE000088.A11	1211	-5		0.6	Al	
LE000089.A11	RE000089.A11	812	957		0.7	Al	
LE000090.A11	RE000090.A11	1021	962		0.7	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.A11	RE000001.A11	178	547		0.7	Al	
LE000002.A11	RE000002.A11	220	604		1.5	Al	
LE000003.A11	RE000003.A11	254	601		0.8	Al	
LE000004.A11	RE000004.A11	284	576		0.7	Al	
LE000005.A11	RE000005.A11	343	509		0.6	Al	
LE000006.A11	RE000006.A11	-9	32		0.8	Al	
LE000007.A11	RE000007.A11	78	431		1.2	Al	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000008.A11	RE000008.A11	107	382		1.0	Al	
LE000009.A11	RE000009.A11	173	408		0.9	Al	
LE000010.A11	RE000010.A11	208	418		0.7	Al	
LE000011.A11	RE000011.A11	236	425		0.6	Al	
LE000012.A11	RE000012.A11	195	334		1.0	Al	
LE000013.A11	RE000013.A11	317	265		3.5	Al	
LE000014.A11	RE000014.A11	23	317		0.6	Al	
LE000015.A11	RE000015.A11	391	335		0.7	Al	
LE000016.A11	RE000016.A11	368	291		0.7	Al	
LE000017.A11	RE000017.A11	519	497		0.7	Al	
LE000018.A11	RE000018.A11	713	596		0.8	Al	
LE000019.A11	RE000019.A11	773	582		1.2	Al	
LE000020.A11	RE000020.A11	821	587		2.3	Al	
LE000021.A11	RE000021.A11	821	587		0.9	Al	
LE000022.A11	RE000022.A11	675	470		0.7	Al	
LE000023.A11	RE000023.A11	988	482		0.6	Al	
LE000024.A11	RE000024.A11	1005	498		0.5	Al	
LE000025.A11	RE000025.A11	706	365		0.7	Al	
LE000026.A11	RE000026.A11	446	298		0.9	Al	
LE000027.A11	RE000027.A11	614	254		0.8	Al	
LE000028.A11	RE000028.A11	927	424		0.6	Al	
LE000029.A11	RE000029.A11	990	450		0.8	Al	
LE000030.A11	RE000030.A11	1010	436		0.8	Al	
LE000031.A11	RE000031.A11	1009	394		0.7	Al	
LE000032.A11	RE000032.A11	1081	344		0.5	Al	
LE000033.A11	RE000033.A11	1133	369		0.9	Al	
LE000038.A11	RE000038.A11	162	867		0.7	Al	
LE000039.A11	RE000039.A11	164	814		0.8	Al	
LE000040.A11	RE000040.A11	321	828		0.6	Al	
LE000041.A11	RE000041.A11	202	777		0.8	Al	
LE000042.A11	RE000042.A11	7	692		0.9	Al	
LE000043.A11	RE000043.A11	27	700		0.8	Al	
LE000044.A11	RE000044.A11	69	707		0.7	Al	
LE000045.A11	RE000045.A11	221	605		1.6	Al	
LE000046.A11	RE000046.A11	365	674		1.3	Al	
LE000047.A11	RE000047.A11	460	824		1.0	Al	
LE000048.A11	RE000048.A11	627	866		1.0	Al	
LE000049.A11	RE000049.A11	640	828		0.9	Al	
LE000050.A11	RE000050.A11	719	919		0.8	Al	
LE000051.A11	RE000051.A11	702	780		0.8	Al	
LE000052.A11	RE000052.A11	734	779		0.5	Al	
LE000053.A11	RE000053.A11	749	796		1.3	Al	
LE000054.A11	RE000054.A11	755	782		1.0	Al	
LE000055.A11	RE000055.A11	828	787		0.6	Al	
LE000056.A11	RE000056.A11	876	832		0.6	Al	
AE000056.A11	BE000056.A11	876	832		0.6	Al	
LE000057.A11	RE000057.A11	993	729		0.6	Al	
LE000058.A11	RE000058.A11	1075	767		0.7	Al	
LE000059.A11	RE000059.A11	883	698		0.8	Al	
LE000060.A11	RE000060.A11	879	637		0.8	Al	
LE000061.A11	RE000061.A11	872	626		1.3	Al	
LE000062.A11	RE000062.A11	921	639		0.7	Al	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000063.A11	RE000063.A11	1027	697		0.6	Al	*d*
LE000064.A11	RE000064.A11	1096	651		1.5	Al	
LE000065.A11	RE000065.A11	40	160		0.6	Al	
LE000066.A11	RE000066.A11	72	23		0.6	Al	
LE000067.A11	RE000067.A11	273	19		1.0	Al	
LE000068.A11	RE000068.A11	417	186		0.6	Al	
LE000069.A11	RE000069.A11	435	220		1.0	Al	
LE000070.A11	RE000070.A11	536	184		0.6	Al	
LE000071.A11	RE000071.A11	615	159		0.6	Al	
LE000072.A11	RE000072.A11	808	140		0.4 x 0.5	Al	
LE000073.A11	RE000073.A11	474	31		0.6	Al	
LE000074.A11	RE000074.A11	482	19		1.0	Al	
LE000075.A11	RE000075.A11	540	81		0.8	Al	
LE000076.A11	RE000076.A11	662	27		0.6	Al	
LE000077.A11	RE000077.A11	960	241		0.8	Al	
LE000078.A11	RE000078.A11	992	232		0.8	Al	
LE000079.A11	RE000079.A11	1118	195		0.9	Al	
LE000080.A11	RE000080.A11	1165	172		0.7	Al	
LE000081.A11	RE000081.A11	1189	223		0.5	Al	
LE000082.A11	RE000082.A11	1051	2		0.5	Al	
LE000083.A11	RE000083.A11	1146	130		0.7 x 0.8	Al	
LE000084.A11	RE000084.A11	1198	105		0.5	Al	
LE000085.A11	RE000085.A11	1226	94		0.8 x 0.9	Al	
LE000086.A11	RE000086.A11	1271	292		0.8	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-538/1
On-Orbit - S32-78-058
Pre-Deintegration - KSC-390C-1028.09, KSC-390C-1028.10, KSC-390C-1028.08
Post Deintegration
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - A11C01, A11C05, A11C07, and A11C08
Clamp Bolts - A11S01A and A11S02A

LDEF LOCATION: A12
EXPERIMENT IDENTIFICATION: S0001
EXPERIMENT TITLE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES
493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay A12 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays that were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 361 features on the A12 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. On the experiment surface, 246 impacts were located. Of these, 219 of the impacts were <0.5 mm in diameter and were not photodocumented, 24 were between 0.5 mm and 1.0 mm in diameter, two were between 1.0 mm and 1.5 mm in diameter, and one was between 1.5 mm and 2.0 mm in diameter. Of the 92 impacts on the experiment-tray flanges and walls, 83 were <0.5 mm in diameter (of which 39 were located on the tray walls, one of which was photodocumented as it was considered to be of interest), 8 were between 0.5 mm and 1.0 mm in diameter (two of which were located on the tray walls), and one was between 1.5 mm and 2.0 mm in diameter. On the experiment-tray clamps, 20 of the 23 impacts identified were <0.5 mm in diameter, one was between 0.5 mm and 1.0 mm in diameter, one was between 1.0 mm and 1.5 mm in diameter, and one was between 1.5 mm and 2.0 mm in diameter. All features were typical of craters produced in aluminum during laboratory hypervelocity impact tests.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	20	83	219	322
>0.5 mm	3	9	27	39
TOTALS	23	92	246	361

The largest impact features identified on tray A12 were (1) a circular ~1.6 mm diameter crater located on the tray surface, (2) a circular ~1.5 mm diameter crater located on the experiment-tray flange, (3) a circular ~0.8 mm diameter crater located on the experiment-tray wall, and (4) a circular ~1.7 mm crater on experiment-tray clamp C06.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft. This inspection identified five features which might be destroyed by attachment of the experiment-tray cover and one feature which would be destroyed by emplacement in the experiment-tray rotator. This latter impact feature was estimated to be ~0.5 mm in diameter. This feature was not examined or

photodocumented, nor was it included in the numerical summary given above. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment tray cover and the tray flanges. One feature each was identified on clamp C01, C02, and C06. For the features identified on C02 and C06, the M&D SIG A-Team requested the ground operations personnel to use an open-end wrench when removing bolts C02A and C06B to avoid damaging the features. This request was followed during tray deintegration from LDEF.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.0625" (1.6 mm) thick experiment-tray flanges.

DOCUMENTATION:

The detailed examination and photodocumentation of tray A12 was conducted on March 23, 1990 in the horizontal position utilizing M&D SIG System #3. The bolts, clamps and shims associated with this tray were also scanned and imaged with M&D SIG System #3; coordinates for all features were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC010001.A12	RC010001.A12	116	4		0.8	Al	
LC020001.A12	RC020001.A12	3	37		1.0	Al	
LC060001.A12	RC060001.A12	65	22		1.7	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.A12	RE000001.A12	1288	313		0.5	Al	*w*
LE000014.A12	RE000014.A12	249	0		0.5	Al	*1*
LE000015.A12	RE000015.A12	818	962		0.8 x 0.9	Al	*x*
LE000016.A12	RE000016.A12	214	997		0.6 x 0.7	Al	*x*
LE000018.A12	RE000018.A12	-40	612		0.5	Al	*x*
LE000033.A12	RE000033.A12	0	535	64	1.5	Al	*2,3,f,z*
LE000034.A12	RE000034.A12	0	446	75	0.6	Al	*3,f,z*
LE000035.A12	RE000035.A12	675	0	68	0.8	Al	*4,f*
LE000036.A12	RE000036.A12	721	0	78	0.8	Al	*4,f*
LE000037.A12	RE000037.A12	1069	0	48	0.5	Al	*4,f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.A12	RE000002.A12	141	180		0.6	Al	
LE000003.A12	RE000003.A12	331	288		0.5	Al	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000004.A12	RE000004.A12	358	295		0.8 x 0.9	Al	*d*
LE000005.A12	RE000005.A12	160	390		0.6	Al	
LE000006.A12	RE000006.A12	321	458		0.8	Al	
LE000007.A12	RE000007.A12	550	173		0.5	Al	
LE000008.A12	RE000008.A12	599	410		1.2	Al	
LE000009.A12	RE000009.A12	1185	390		0.7	Al	
LE000010.A12	RE000010.A12	1174	80		0.6	Al	
LE000011.A12	RE000011.A12	1032	69		0.7	Al	
LE000012.A12	RE000012.A12	1040	150		0.8	Al	
LE000013.A12	RE000013.A12	971	112		0.5	Al	
LE000017.A12	RE000017.A12	17	675		1.6	Al	*x*
LE000019.A12	RE000019.A12	101	898		0.8	Al	*x*
LE000020.A12	RE000020.A12	455	849		0.7	Al	*x*
LE000021.A12	RE000021.A12	485	714		1.0	Al	*x*
LE000022.A12	RE000022.A12	618	708		0.8	Al	*x*
LE000023.A12	RE000023.A12	553	647		0.7	Al	*x*
LE000024.A12	RE000024.A12	227	615		0.6	Al	*x*
LE000025.A12	RE000025.A12	228	588		0.6	Al	*x*
LE000026.A12	RE000026.A12	165	543		1.0	Al	*x*
LE000027.A12	RE000027.A12	587	488		0.4 x 0.5	Al	*5*
LE000028.A12	RE000028.A12	720	673		0.5	Al	
LE000029.A12	RE000029.A12	723	825		0.8	Al	
LE000030.A12	RE000030.A12	967	761		0.5	Al	
LE000031.A12	RE000031.A12	1205	692		0.5	Al	
LE000032.A12	RE000032.A12	1245	854		0.5 x 0.6	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Image taken at 30° to right of normal to crater.
2 - Wrong location stated in comments in image file; should be "Left tray lip".
3 - Image taken at 45° to left of normal to crater.
4 - Image taken at 45° below normal to crater.
5 - Wrong camera orientation entered into comment in image file; image is not rotated 180°.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-78-29
Pre-Deintegration - KSC-390C-1028.01, KSC-390C-1069.04, KSC-390C-1069.05
Post Deintegration - KSC-390C-2163.01 through KSC-390C-2163.03
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - A12C01, A12C02, A12C05, and A12C06

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION: B01
TRAY IDENTIFICATION: S0001
EXPERIMENT PURPOSE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES

493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay B01 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays that were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 36 features on the B01 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of the 36 impacts found, 15 were <0.5 mm and were not imaged due to the 0.5 mm diameter criteria for photodocumentation. Of the 24 imaged impacts, three were located on the tray flanges and ranged in diameter from 0.5 mm to 1.0 mm, one was located on the edge of bolt C01C and was ~0.3 mm in diameter, and the remaining 20 impacts were located on the aluminum tray surface and ranged in diameter from 0.5 mm to 0.9 mm. All features were typical of craters produced in aluminum during laboratory hypervelocity impact tests.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	4			15*@
>0.5 mm		3	20	23
TOTALS	4			38

* - The locations of the "Too Smalls" were not documented.
@ - The survey for "Too Smalls" was not conducted.

The largest impact features identified on tray B01 were (1) a circular impact ~0.9 mm in diameter located on the right tray flange, and (2) a circular impact ~0.9 mm in diameter located on the aluminum tray surface.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft and the M&D SIG identified nine features that might be damaged by the placement of the experiment-tray cover and two additional features that could be damaged or destroyed by the placing of the experiment tray within the experiment tray stand. The latter impact features were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in seven locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges. Two features were identified on tray clamp bolts C05A, and C08C that might be

damaged as a result of the tray removal procedures (i.e., by the socket wrench used to remove tray clamp bolts).

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations of the 0.0625" (1.6 mm) thick experiment-tray flanges and no bulges or spalls on the back of the tray flanges. There were shadow features on the black painted back surface of the experiment tray.

DOCUMENTATION:

Examination and photodocumentation of tray B01 was conducted on March 16, 1990 in the vertical position utilizing M&D SIG System #2. The bolts, clamps and shims associated with this tray were scanned with M&D SIG System #3. All impact coordinates measured on this tray were determined using a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experimental-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LS010001.B01	RS010001.B01	-1.0	10.0		0.3	Stain. Steel	

Impact Features Imaged on Experimental-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.B01	RE000001.B01	-34	334		0.5	Al	1
LE000014.B01	RE000014.B01	333	-19		0.5	Al	
LE000016.B01	RE000016.B01	1275	620		1.0	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.B01	RE000002.B01	215	40		0.7	Al	
LE000003.B01	RE000003.B01	406	35		0.9	Al	
LE000004.B01	RE000004.B01	350	112		0.8	Al	
LE000005.B01	RE000005.B01	368	109		0.7	Al	
LE000006.B01	RE000006.B01	480	270		0.5	Al	
LE000007.B01	RE000007.B01	550	345		0.5	Al	
LE000008.B01	RE000008.B01	915	165		0.8	Al	
LE000009.B01	RE000009.B01	815	385		0.8	Al	
LE000010.B01	RE000010.B01	1070	430		0.5	Al	
LE000011.B01	RE000011.B01	1158	261		0.6	Al	
LE000012.B01	RE000012.B01	815	3		0.8	Al	
LE000013.B01	RE000013.B01	575	-18		0.6	Al	
LE000015.B01	RE000015.B01	1280	334		0.5	Al	
LE000017.B01	RE000017.B01	850	620		0.9	Al	
LE000018.B01	RE000018.B01	67	645		0.5	Al	
LE000019.B01	RE000019.B01	134	750		0.5	Al	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000020.B01	RE000020.B01	272	740		0.5	Al	
LE000021.B01	RE000021.B01	297	755		0.6	Al	
LE000022.B01	RE000022.B01	360	780		0.7	Al	
LE000023.B01	RE000023.B01	250	785		0.5	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Wrong magnification input into image file, should be 4.0X.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439, L-83-06439
On-Orbit - S32-78-36
Pre-deintegration - KSC-390C-1066.11, KSC-390C-1069.01, KSC-390C-1069.02
Post Deintegration - KSC-390C-1653.03, KSC-390C-1653.12
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - B01C02, B01C05, B01C06, and B01C08
Clamp Bolts - B01S05A, B01S08C

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION: B02
EXPERIMENT IDENTIFICATION: S0001
EXPERIMENT TITLE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES
493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay B02 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays that were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 76 features on the B02 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of these, 65 features from all surfaces were found to smaller in diameter than the 0.5 mm photodocumentation threshold. Five features were photodocumented from the aluminum collector surfaces, four of which were between 0.5 mm and 1.0 mm in diameter, and one feature that was between 1.0 mm and 1.5 mm in diameter. Three features were found on the tray lips that measured between 0.5 mm and 1.0 mm in diameter; an additional two features were documented that resided on the 3" high (7.6 cm) inner-tray walls and were between 1.0 mm and 1.5 mm in diameter. One (LE000009.B02) of the two features on the tray walls exhibited debris spray associated with the impact. Only four features were identified on the various clamping hardware associated with this tray, four of which were less than 0.5 mm in diameter and one that was between 0.5 mm and 1.0 mm in diameter from clamp C01. All features exhibited characteristics typical of craters formed in aluminum during laboratory hypervelocity impact experiments.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	3			65*
>0.5 mm	1	5	5	11
TOTALS	4			76

* - The locations of the "Too Smalls" were not documented.

The largest impact features identified on tray B02 were (1) a circular ~0.7 mm diameter feature on the aluminum collector surface, (2) a circular ~0.6 mm feature from the experiment-tray flange, (3) a large ~1.4 mm diameter crater on a tray wall, and (4) an ~0.5 mm crater on clamp C01.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 20, 1990 while the experiment-tray was mounted on the spacecraft and the M&D SIG identified four features that might be damaged by the emplacement of the experiment-tray cover. In an effort to protect the features within the experiment-tray cover area, the cover

gasket was cut in the four locations opposite the corresponding tray-flange locations in order to prevent the experiment-tray cover from coming into contact with these features and to provide a stand-off between the cover and the tray flanges. No features were found on the outer tray flanges that could be damaged by placing the experiment tray with the experiment-tray stand. One feature each was identified on clamps C01 and C02, while two features were identified on clamp C08.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations or spallation features on the 0.0625" (1.6 mm) thick experiment-tray flanges. During the general inspection a bulge was noticed on one of the experiment-tray flanges, however, the front of the flange was covered by the experiment-tray cover. Once the tray was moved to the M&D SIG area and the cover was removed it was determined that an impact did not cause the bulge.

DOCUMENTATION:

Examination and photodocumentation of tray B02 was conducted on March 6, 1990 in the horizontal position utilizing M&D SIG System #3. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3. The coordinates for all features associated with this tray were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC010001.B02	RC010001.B02	93	21		0.5	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000006.B02	RE000006.B02	716	947		0.6	Al	
LE000007.B02	RE000007.B02	674	-3		0.5	Al	
LE000008.B02	RE000008.B02	1172	-9		0.5	Al	
LE000009.B02	RE000009.B02	0	201	60	1.1	Al	*1,d*
LE000010.B02	RE000010.B02	1260	940	25	1.4	Al	*2*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.B02	RE000001.B02	80	446		0.6	Al	
LE000002.B02	RE000002.B02	292	523		0.7	Al	
LE000003.B02	RE000003.B02	156	363		1.2	Al	
LE000004.B02	RE000004.B02	1054	650		0.6	Al	*d*
LE000005.B02	RE000005.B02	668	431		0.7	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Image taken at 61° from normal of crater.
2 - Image taken at 48° from normal of crater and 15° to right of normal.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-78-16
Pre-Deintegration - KSC-390C-1065.07, KSC-390C-1065.08, KSC-390C-1006.05
Post Deintegration - KSC-390C-1659.05
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - B02C01, B02C02, B02C05, and B02C08

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION: **B03**
EXPERIMENT IDENTIFICATION: **A0138-1 THROUGH A0138-10**
EXPERIMENT TITLE: **FRENCH COOPERATIVE PAYLOAD (FRECOPA)**
PRINCIPAL INVESTIGATOR: **SEE LIST AT END OF DOCUMENT**

SUMMARY OF OBSERVATIONS

Tray B03 was a 12"-deep (30.5 cm), partially active experiment tray that housed a total of ten different experiments. The only totally passive experiment on this tray was A0138-1, Study of Meteoroid Impact Craters on Various Materials. The tray was divided into approximately six equal parts, two of which contained the batteries (28 volt and 7.5 volt) that activated the three, clam-shell like boxes containing experiments A0138-2 through A0138-10. Each battery compartment was covered by a passive thermal control systems in the form of thermal blankets. These thermal protection systems consisted of a 150 μm thick outer layer of teflon-coated fiberglass mesh overlying a 25 μm thick aluminized sheet of mylar; the metalized coating of the mylar was on the back surface. For a detailed list of the various materials, and an explanation of the experimental objectives associated with each of the ten FRECOPA experiments see *The Long Duration Exposure Facility (LDEF), Mission 1 Experiments* handbook (NASA SP-473; Clark, Kinard, Carter, and Jones, eds., 1984).

Morphologically, all craters found in aluminum were typical of craters formed during laboratory hypervelocity impact experiments. The one aluminum penetration possessed a raised rim on the front side similar to those associated with craters in aluminum, while the back side exhibited a typical aluminum spallation morphology. Penetrations through the thermal insulation blankets possessed two distinct characteristics. First, penetrations through the outer teflon-coated fiberglass mesh varied in the degree of damage depending on whether one or more fibers were effected by the passing projectile. Effected fiber generally exhibited a frayed appearance. The morphology of the penetrations through the inner metalized mylar film was that of simple holes through this material.

The M&D SIG survey identified a total of 43 features on the B03 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the various experimental surfaces; of these, 11 were photodocumented. Six features were documented that resided within the two thermal blankets overlying the battery compartments. Only one (~0.4 mm in diameter) of these six features was larger than the 0.3 mm diameter penetration threshold, however, the other five features were document as they represented the only penetrations through this type of thermal protection system. Two other documented features represented penetrations instead of craters. One of these was an ~0.8 mm in diameter penetration through an aluminum foil/film, an ~0.1 mm diameter crater was found within the underlying aluminum plate on the A0138-1. The other penetration was through the lower right-hand corner of the 1 mm aluminum plate on the active canister occupying the lower right-hand one sixth area of the B03 tray. The remaining three documented features were all into aluminum mounting plates. No impacts were found on the eight clamps or bolts holding the experiment tray into Bay B03.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			4	4*
>0.3 mm			1	1
<0.5 mm				34*
>0.5 mm			4	4
TOTALS				43

* - The locations of the "Too Smalls" were not documented.

The largest impact features identified on tray B03 were (1) an ~1.6 mm diameter penetration hole through the 1 mm aluminum cover plate for one of the calm-shell like canisters, (2) an ~0.4 mm diameter penetration through one of the two thermal insulation blankets, and (3) an ~1.1 mm diameter crater into the same aluminum plate as (1).

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 20, 1990 while the experiment-tray was mounted on the spacecraft. No impact features were identified on the tray flanges, clamps, or bolts during this inspection.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick experiment-tray flanges. However, there was strong shadowing effects visible on the black paint covering the back of the B03 tray. One of these shadows (of a bolt) was so sharp in appearance and outline that you could easily count the threads on the bolt.

DOCUMENTATION:

When the tray cover was removed from B03 the M&D SIG A-Team noted one large tear/rip in the thermal insulation blanket cover the upper right-hand one sixth of the experiment tray. Several smaller tears were noticeable within this blanket, as well as the other blanket covering the upper left-hand one sixth portion of the tray. Photographs were taken by the M&D SIG A-Team of these features. Pre-deintegration photographs taken by the LDEF photographic crew revealed that these tears/rips were present prior to removal of the tray from the spacecraft.

Examination and photodocumentation of tray B03 was conducted on March 6, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #1. The bolts, clamps, and shims associated with this tray were scanned with M&D SIG System #3; however, no features were located during this survey.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	58	948	333	-27
Center	617	946	612	-28
Far Right	1176	943	1170	-30

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.B03	RE000001.B03	913	829		0.2	TB	*1*
LE000002.B03	RE000002.B03	362	564		0.2	TB	*1*
LE000003.B03	RE000003.B03	399	485		0.4	TB	*1*
LE000004.B03	RE000004.B03	18	195		0.6	Al	
LE000005.B03	RE000005.B03	759	243		0.8	Al	
LE000006.B03	RE000006.B03	880	680		0.2	TB	*2*
LE000007.B03	RE000007.B03	1025	550		0.1	TB	
LE000008.B03	RE000008.B03	1036	459		ND	TB	*3*
LE000009.B03	RE000009.B03	836	353		0.5	Al	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000010.B03	RE000010.B03	1177	48		1.1	Al	
LE000011.B03	RE000011.B03	1210	45		1.6	Al	*4, i*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined
TB - Thermal Insulation Blanket

1 - Penetration.
2 - May not have been an impact related feature.
3 - Piece of thin aluminum film from TRW Aluminized-Kapton material.
4 - Penetrations through 1 mm aluminum plate; diameter of hole on backside of aluminum plate ~0.8 mm in diameter.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 84-07170
On-Orbit - S32-77-058
Pre-Deintegration - KSC-390C-1065.01, KSC-390C-1065.02, KSC-390C-834.03, KSC-390C-834.02
Post Deintegration - KSC-390C-1646.09, KSC-390C-1708.01, KSC-390C-1708.02
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - B03C01 , B03C03 , B03C06 , and B03C08

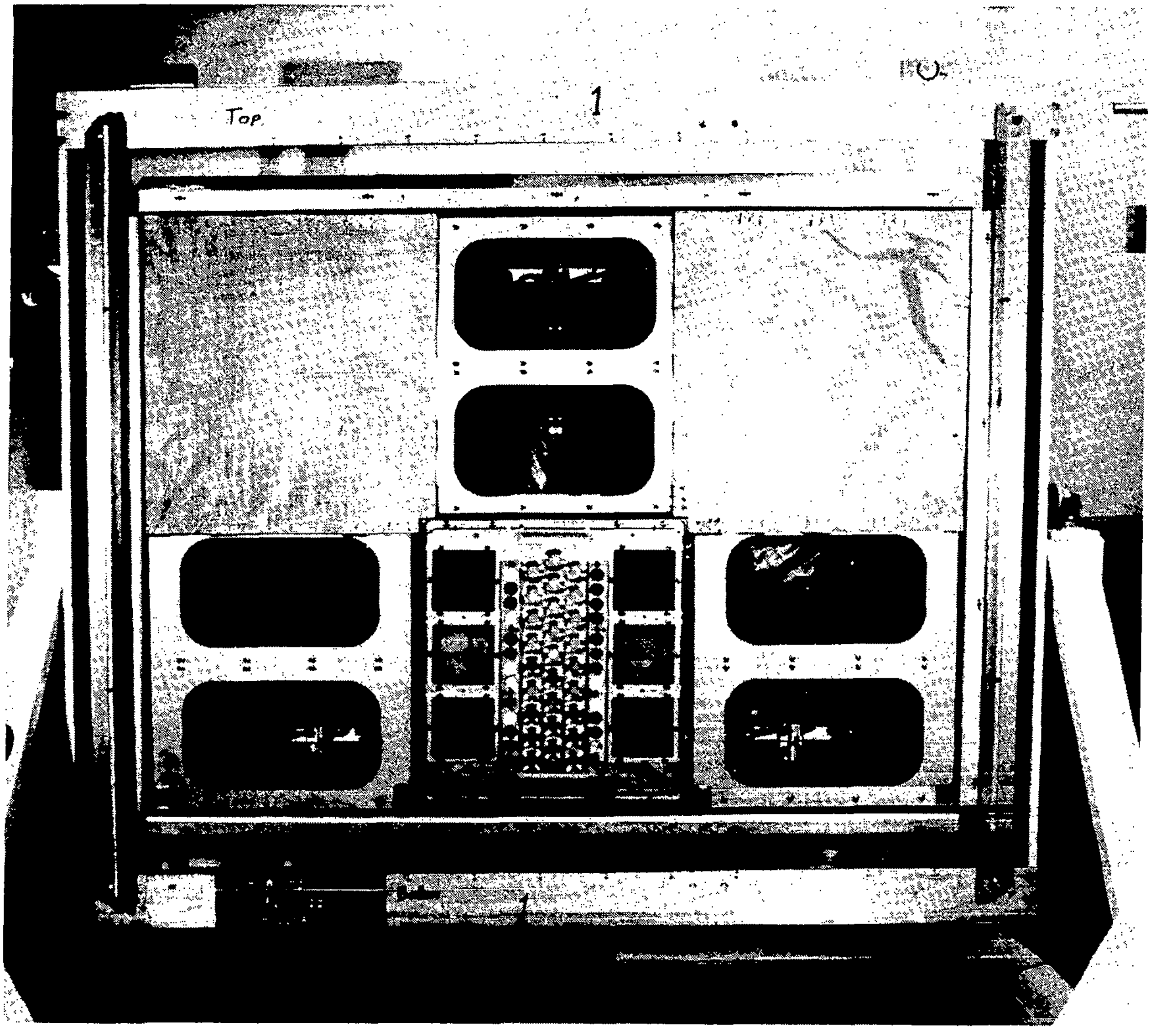
ACCOMPANYING FIGURES:

Figure B03-1. This post-deintegration view shows the front of the entire B03 experiment tray.

FRENCH COOPERATIVE PAYLOAD (FRECOPA)

A0138-1 - Study of Meteoroid Impact Craters on Various Materials; J-C. Mandeville, CERT/ONERA-DERTS, Toulouse, France.
A0138-2 - Attempt at Dust Debris Collection with Stacked Detectors; J-C. Mandeville, CERT/ONERA-DERTS, Toulouse, France.
A0138-3 - Thin Metal Film and Multilayers Experiment; J.P. Delaboudiniere, CNRS/LPSP, Verrieres le Buisson, France.
A0138-4 - Vacuum-Deposited Optical Coatings Experiment; A. Malherbe, Marta S.A., Rueil Malmaison, France.
A0138-5 - Ruled and Holographic Gratings Experiment; G. Moreau, Instruments S.A., Longjumeau, France.
A0138-6 - Thermal Control Coatings Experiment; A. Paillous, CERT/ONERA-DERTS, Toulouse, France.
A0138-7 - Optical Fibers and Components Experiment; J. Bourrieau, CERT/ONERA-DERTS, Toulouse, France.
A0138-8 - Effects of Space Exposure of Some Epoxy Matrix Composites on Their Thermal Expansion and Mechanical Properties; R. Elberg, Marta S.A., Le Chesnay, France.
A0138-9 - The Effects of the Space Environment on Composite Materials; M. Parcelier, Aerospatial, Les Mureaux, France.

A0138-10 - Microwelding of Various Metallic Materials Under Ultrvacuum; J.P. Assie, Aerospatial, Cannes, France.



LDEF LOCATION: B04
TRAY IDENTIFICATION: A0054
EXPERIMENT TITLE: SPACE PLASMA HIGH-VOLTAGE DRAINAGE EXPERIMENT
PRINCIPAL INVESTIGATOR: W. TAYLOR
TRW SPACE AND TECHNOLOGY GROUP
REDONDO BEACH, CALIFORNIA

SUMMARY OF OBSERVATIONS

Tray B04 was a 3"-deep (7.6 cm), active peripheral tray on the trailing edge of the spacecraft. The A0054 experiment consisted of two experiment trays B04 and D10 containing large numbers of dielectric samples under electrical stress in space. The samples include encapsulated solar cell samples and thin polymeric films such as Mylar, FEP Teflon, and Kapton/vacuum-deposited Aluminum bonded by a conductive epoxy cement to an underlying KEVLAR honeycomb support structure. Each dielectric sample is equipped with a self-contained battery and power processor unit to furnish an applied bias voltage.

The impacts on the surface of the gold Kapton/vacuum-deposited Aluminum were very difficult to see. Upon initial visual inspection of the experiment there appeared to be a lot of impacts into the outer surfaces of the experiment but on closer inspection with the microscope, these impacts turned out to be small tears in the surface. The morphology of the features on the experiment-tray flanges, and experiment-tray clamps were all typical of hypervelocity impact craters into aluminum.

The M&D SIG survey identified a total of 113 features on the B04 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the experimental tray surfaces. Of the 113 impacts found, 93 were located on the experimental surface, ten were located on the experiment-tray flanges, and the remaining 10 were located on experiment-tray clamps C03-C07. Of these, 96 features did not meet the >0.5 mm diameter criteria for impact features or the >0.3 mm diameter criteria for penetrations so these features were not imaged. Out of the 17 features that were imaged, ten were classified as penetrations through the Kapton deposited aluminum and ranged in size from 0.2 mm to 0.7 mm in diameter. The remaining seven imaged features were classified as impact features into aluminum and ranged in size from 0.4 mm to 0.8 mm in diameter.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			2	2
>0.3 mm			8	8
<0.5 mm	10	10	77	97
>0.5 mm			6	6
TOTALS	10	10	93	113

The largest impact features identified on tray B04 were (1) an oblique impact ~0.7 x 0.7 mm located on the surface of the A0054 experiment, (2) a circular impact ~0.7 mm in diameter located on the aluminum divider plate, and (3) an ~0.7 mm in diameter penetration located on the tray surface.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft and the M&D SIG identified three features that might be damaged by the placement of the experiment-tray cover and one additional feature that could be damaged or destroyed by the placement of the experiment tray within the experiment tray stand. The latter impact feature was not examined or photodocumented, nor was it included in the numerical summary given above. In an effort to protect the more interesting feature within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations of the 0.0625" (1.6 mm) thick experiment-tray flanges and no bulges or spalls on the back of the tray flanges.

DOCUMENTATION:

On March 20, 1990 the A0054 experiment tray was inspected and photodocumented in the vertical position utilizing M&D SIG System #1 and impact coordinates were determined using Coordinate Registration System #2. The detailed inspection of the clamps and bolts was also performed on March 20, 1990, using M&D SIG System #3; coordinates were determined using a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.B04	RE000001.B04	944	790		0.2	Al	
LE000002.B04	RE000002.B04	1136	936		0.5	Kapton	*k*
LE000003.B04	RE000003.B04	1139	936		0.3	Kapton	
LE000004.B04	RE000004.B04	1102	501		0.3	Kapton	
LE000005.B04	RE000005.B04	920	346		0.7	Al	
LE000006.B04	RE000006.B04	841	338		0.3	Kapton	*1*
LE000007.B04	RE000007.B04	706	558		0.4	Al	
LE000008.B04	RE000008.B04	476	509		0.5	Kapton	
LE000009.B04	RE000009.B04	86	477		0.3	Kapton	
LE000010.B04	RE000010.B04	216	144		0.3	Kapton	
LE000011.B04	RE000011.B04	361	33		0.7	Kapton	
LE000012.B04	RE000012.B04	719	144		0.2	Kapton	*2,c*
LE000013.B04	RE000013.B04	947	110		0.6 x 0.7	Al	
LE000014.B04	RE000014.B04	1002	53		0.6	Al	
LE000015.B04	RE000015.B04	1108	110		0.6	Al	*3*
LE000016.B04	RE000016.B04	1179	164		0.7 x 0.8	Al	
LE000017.B04	RE000017.B04	1230	93		0.5	Kapton	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Wrong coordinates (X = 853, Y = 301) input into image file.
2 - Delamination zone around penetration ~1.1 x 1.4 mm.
3 - Halo of particles around impact not shown in photo.

OTHER PHOTODOCUMENTATION:

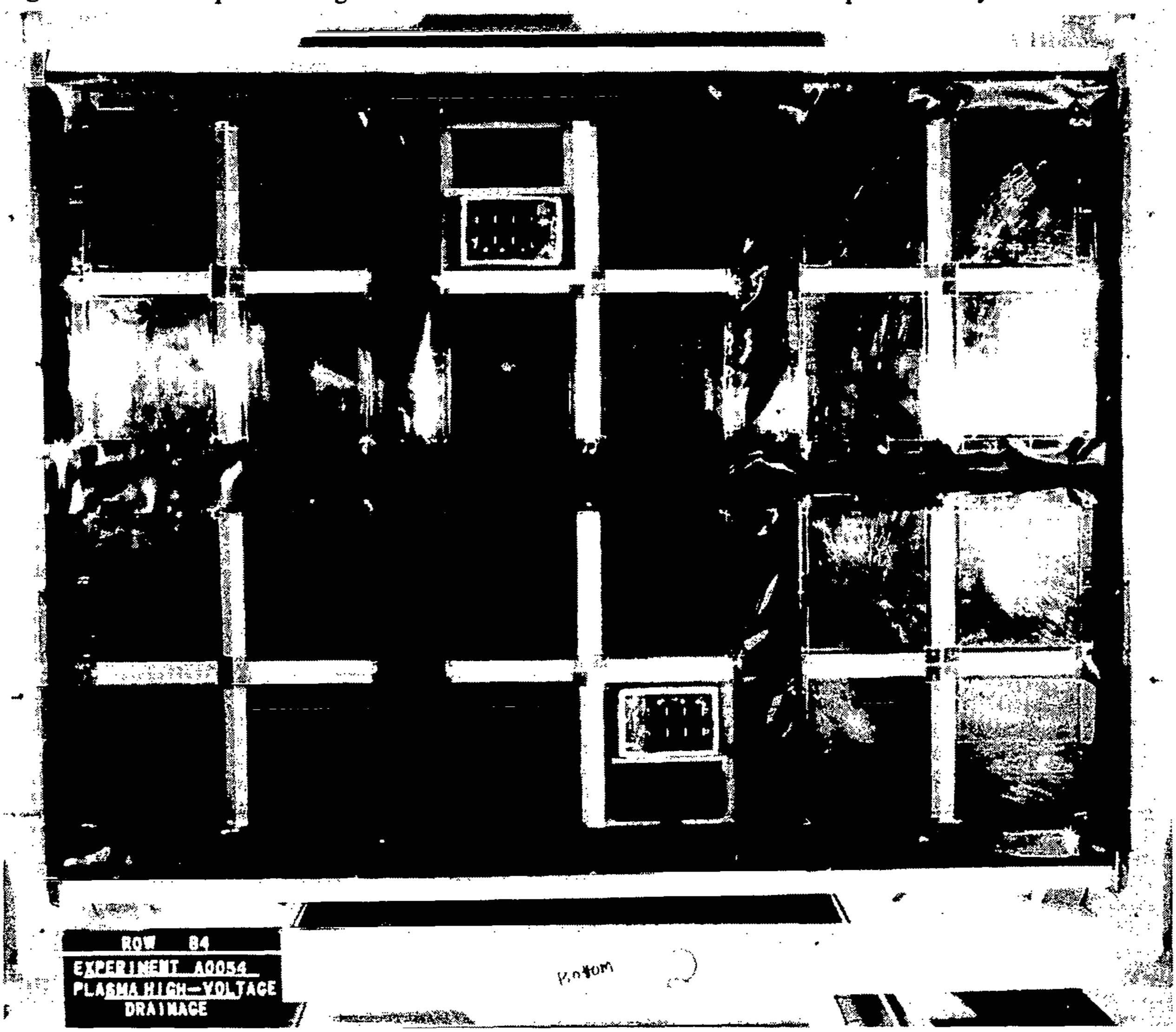
Pre-Flight - L-84-7086
On-Orbit - S32-77-027
Pre-deintegration - KSC-390C-832.06, KSC-390C-1065.04, KSC-390C-1065.06
Post Deintegration - KSC-390C-2116.12
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - B04C01, B04C03, B04C05, and B04C06

ACCOMPANYING FIGURES:

Figure B04-1. This post-deintegration view shows the front of the entire B04 experiment tray.



LDEF LOCATION:	**B05**
EXPERIMENT IDENTIFICATION:	**A0178**
EXPERIMENT TITLE:	**A HIGH-RESOLUTION STUDY OF ULTRA-HEAVY COSMIC-RAY NUCLEI**
PRINCIPAL INVESTIGATOR:	**D. O'SULLIVAN DUBLIN INSTITUTE FOR ADVANCED STUDIES DUBLIN, IRELAND**

SUMMARY OF OBSERVATIONS

Bay B05 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46" long (~116.8 cm), 10" (25.4 cm) in diameter, 6063-T6 aluminum cylinders (1.9 mm thick) which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with an ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (space facing) of FEP teflon (~120 μm thick) backed with a thin layer of vapor-deposited silver/inconel (~200 to 300 Å thick), which in turn was backed by DC1200 primer and Chemglaze Z306 black conductive paint (~80 to 100 μm thick). The blankets were attached to a 40-5052 aluminum support frame by ~1" x 2" (~2.5 x 5.1 cm) strips of velcro.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of the resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted teflon material. Commonly, the teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. Many possessed several sharp, distinct rings, while other exhibited a more continuous halo phenomenon where the changes from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impact craters into aluminum.

The M&D SIG survey identified a total of 85 features on the B05 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the thermal insulation blanket. Fifty-eight features from the blanket were below the 0.3 mm diameter photodocumentation threshold, nine features were between 0.3 mm and 1.0 mm in diameter and were photodocumented along with one small oblique impact ~0.1 x 0.2 mm in diameter. Thirteen features were found on the tray flanges, 12 of which were <0.5 mm in diameter and one of which was between 0.5 mm and 1.0. The remaining one feature was located while scanning the associated bolts, clamps and shims for tray B05. The one impact documented was located on experiment-tray clamp C02 and was ~0.5 mm in diameter.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			58	58
>0.3 mm			9	9
<0.5 mm	4	12		16
>0.5 mm	1	1		2
TOTALS	5	13	67	85

The largest impact feature identified on tray B05 was an ~0.8 mm penetration hole through the thermal blanket.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft and identified three features that might be damaged or destroyed by the emplacement of the experiment-tray cover. Although these features were identified in the area where the experiment-tray cover would be placed, no alterations to the tray-cover gasket were required.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick tray flanges.

DOCUMENTATION:

Examination and photodocumentation of tray B05 was conducted on March 21, 1990 in the vertical position utilizing M&D SIG System and Coordinate Registration Systems #1. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a small metric scale.

Bolt-Hole Registration - Not Determined

Fiducial Mark Locations (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	236	905	248	26
Middle	619	901	612	22
Far Right	1019	898	1022	23

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC020001.B05	RC020001.B05	94	6		0.5	Al	
AC020001.B05	BC020001.B05	94	6		0.5	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000011.B05	RE000011.B05	218	-38		0.5	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.B05	RE000001.B05	420	685		0.4	TB	
LE000002.B05	RE000002.B05	1070	670		0.5 x 0.8	TB	
LE000003.B05	RE000003.B05	417	348		0.4	TB	
LE000004.B05	RE000004.B05	680	390		0.6	TB	
LE000005.B05	RE000005.B05	1090	585		0.4 x 0.6	TB	
LE000006.B05	RE000006.B05	945	400		0.5	TB	
LE000007.B05	RE000007.B05	310	230		0.8	TB	
LE000008.B05	RE000008.B05	400	825		0.5	TB	*v*
LE000009.B05	RE000009.B05	945	880		0.1 x 0.2	TB	*v*
LE000010.B05	RE000010.B05	890	85		0.3	TB	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

TB - Thermal Blanket (teflon, silver-inconel, binder, and paint)

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-331/11
On-Orbit - S32-76-107
Pre-Deintegration - KSC-390C-1035.10, KSC-390C-1035.11, KSC-390C-1035.08, KSC-390C-1030.11
Post Deintegration - KSC-390C-2151.04
M&D SIG Photos - S90-43521, S90-43522 - Left 1/3 of Thermal Blanket; front and back views.
S90-43519, S90-43520 - Middle 1/3 of Thermal Blanket;front and back views.
S90-43517, S90-43518 - Right 1/3 of Thermal Blanket; front and back views.

ARCHIVED MATERIALS:

Clamps - B05C01, B05C02, B05C06, and B05C08
Clamp Bolts - B05S05A
Thermal Blanket - (B05E00A) The U.S. third of the thermal blanket (minus the Materials SIG specimen) resides at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds (minus the Materials SIG grounding-strap specimen) is being archived at ESTEC in The Netherlands. Each blanket third was marked with two small crosses (see the Fiducial Mark table above) for indexing and reconstruction purposes.

LDEF LOCATION: B06
EXPERIMENT IDENTIFICATION: S0001
EXPERIMENT TITLE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES
NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay B06 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays that were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 172 features on the B06 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of these, 151 features from all surfaces were found to be less than the 0.5 mm photodocumentation threshold. Of the 151 features too small to photodocument, 74 were located on the aluminum tray surface, 65 were located on the tray flange, and 12 were located on the clamps, bolts and shims. Sixteen features were photodocumented from the aluminum collector surfaces, 12 of which were between 0.5 mm and 1.0 mm in diameter, three of which were between 1.0 mm and 1.5 mm in diameter, and one that was >1.5 mm in diameter. Four features were documented on the experimental-tray flanges and ranged in diameter from 0.6 mm to 1.0 mm, and one was documented on the experiment-tray clamp C03 and was ~0.6 mm in diameter. All features exhibited characteristics typical of craters formed in aluminum during laboratory hypervelocity impact experiments.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	12	65	74	151
>0.5 mm	1	4	16	21
TOTALS	13	69	90	172

The largest impact feature found on tray B06 measured ~1.6 mm in diameter located on the aluminum experimental surface; there were 5 other impact features with diameters > 1 mm.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft and identified five features that might be damaged by the placement of the experiment-tray cover. Although, four features were located that might be damaged it was not deemed necessary to cut the gasket for any of these impacts.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges or spallation features on the 0.0625" (1.6 mm) thick experiment-tray flanges or backside.

DOCUMENTATION:

Examination and photodocumentation of tray B06 was conducted on March 26 and 27, 1990 in the vertical position utilizing M&D SIG System #3. The bolts, clamps and shims associated with this tray were also scanned and imaged using M&D SIG System #3. The coordinates for all features associated with this tray were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC030001.B06	RC030001.B06	21	4		0.6	Al	*1*

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000017.B06	RE000017.B06	857	-37		1.0	Al	*d*
LE000018.B06	RE000018.B06	520	980		0.6	Al	*j*
LE000019.B06	RE000019.B06	0	240	-15	0.6	Al	*w*
LE000020.B06	RE000020.B06	0	750	-10	1.0	Al	*w*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.B06	RE000001.B06	343	155		1.6	Al	*x*
LE000002.B06	RE000002.B06	75	485		0.9	Al	*x*
LE000003.B06	RE000003.B06	245	483		0.6	Al	*x*
LE000004.B06	RE000004.B06	262	705		0.5 x 1.0	Al	*2,x*
LE000005.B06	RE000005.B06	266	712		0.5 x 0.5	Al	*x*
LE000006.B06	RE000006.B06	395	825		0.8	Al	*x*
LE000007.B06	RE000007.B06	390	790		0.6	Al	*x*
LE000008.B06	RE000008.B06	503	552		0.8	Al	*x*
LE000009.B06	RE000009.B06	555	863		1.0	Al	*x*
LE000010.B06	RE000010.B06	955	130		0.8	Al	*x*
LE000011.B06	RE000011.B06	1057	268		1.5	Al	*x*
LE000012.B06	RE000012.B06	740	490		0.8	Al	*x*
LE000013.B06	RE000013.B06	810	605		0.7	Al	*x*
LE000014.B06	RE000014.B06	705	720		0.7	Al	*x*
LE000015.B06	RE000015.B06	980	855		0.7	Al	*x*
LE000016.B06	RE000016.B06	1105	720		0.7	Al	*x*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Wrong coordinates (X = 0, Y = 0) input into image file.
2 - Red ejecta pattern on possible oblique surface.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-76-105
Pre-Deintegration - KSC-390C-1033.01, KSC-390C-1033.02
Post Deintegration - KSC-390C-2288.02
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - B06C03, B06C04, B06C06, and B06C08
Clamp Bolts - B06S07A
Clamp Shims - B06H07

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION: B07
EXPERIMENT IDENTIFICATION: A0178
EXPERIMENT TITLE: A HIGH-RESOLUTION STUDY OF ULTRA-HEAVY COSMIC-RAY NUCLEI
PRINCIPAL INVESTIGATOR: D. O'SULLIVAN
DUBLIN INSTITUTE FOR ADVANCED STUDIES
DUBLIN, IRELAND

SUMMARY OF OBSERVATIONS

Bay B07 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46" long (~116.8 cm), 10" (25.4 cm) in diameter, 6063-T6 aluminum cylinders (1.9 mm thick) which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with an ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (space facing) of FEP teflon (~120 μm thick) backed with a thin layer of vapor-deposited silver/inconel (~200 to 300 Å thick), which in turn was backed by DC1200 primer and Chemglaze Z306 black conductive paint (~80 to 100 μm thick). The blankets were attached to a 40-5052 aluminum support frame by ~1" x 2" (~2.5 x 5.1 cm) strips of velcro.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of the resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted teflon material. Commonly, the teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. Many possessed several sharp, distinct rings, while other exhibited a more continuous halo phenomenon where the changes from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impact craters into aluminum.

The M&D SIG survey identified a total of 521 features on the B07 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the thermal insulation blanket. Of these, 436 were found on the thermal blanket, all but a few representing penetration through the blanket. Three hundred and seventy six features from the blanket were below the 0.3 mm diameter photodocumentation threshold, 57 features were between 0.3 mm and 1.0 mm in diameter, and 3 features were photodocumented that were between 1.0 mm and 1.5 mm in diameter. Fifty eight features were found on the tray flanges, 53 of which were <0.5 mm in diameter, 4 of which were between 0.5 mm and 1.0 mm in diameter, and 1 of which were between 1.0 mm and 1.5 mm in diameter. The remaining 27 features were located while scanning the associated bolts, clamps and shims for Tray B07. Twenty five features on clamps (C01-C08) were <0.5 mm in diameter and 2 were between 0.5 mm and 1.0 mm in diameter, one each on clamps C01 and C08. Some black debris was found within one feature with an estimated diameter of ~0.3 mm on clamp C08.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			376	376
>0.3 mm			60	60
<0.5 mm	25	53		78
>0.5 mm	2	5		7
TOTALS	27	58	436	521

The largest impact features identified on tray B07 were (1) an ~1.1 mm penetration hole through the thermal blanket, (2) an ~1.3 mm crater located on the experiment-tray flange, and (3) two ~0.5 mm craters on experiment-tray clamps C01 and C08. The largest non-circular feature on this tray was an elliptical penetration hole that measured ~0.8 x 0.9 mm along the semi-minor and -major axes, respectively.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 22, 1990 while the experiment-tray was mounted on the spacecraft and identified four features that might be damaged by the emplacement of the experiment-tray cover and only one feature that could be damaged or destroyed by the placing of the experiment-tray within the experiment-tray stand. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges. One feature each was identified on Clamps C01, C03, C05, and C08. The feature on clamp C01 possessed associated debris spray, while the feature on clamp C05 was located near bolt C05A. One large feature (Feature #1) was estimated to be larger than 1 mm in diameter; a debris spray could be seen in association with this feature. Several photographs were taken of this feature by the M&D SIG A-Team (Roll 59, Frames 16-17).

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of tray B07 was conducted on March 27, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #1. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale.

One impact on the thermal blanket penetrated the velcro that was attached to the backside of the blanket and the aluminum frame supporting the blanket above the experimental canisters; a crater was visible in the aluminum frame beneath this feature. Both pieces of velcro (*i.e.*, the hook and the loop portions) from below LE000036.B07 were removed when the blanket was trisected, removed, and packaged for shipment in order to maintain their relationship in the hope of recovering projectile materials. This particular third of the thermal blanket from tray B07 was shipped to ESTEC in Noordwijk, The Netherlands.

During the interior tray inspection that was performed following the removal of the thermal blanket an apparent penetration related feature was found on one of the aluminum canister housing the track detectors. The materials located on this cylinder looked like glue or melted plastic and contained some fibrous looking particles, as well as several other particle types. The feature was located on the top of the three cylinders ~100 mm below the tray lip.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	62	946	58	-28
Center	621	943	617	-31
Far Right	1180	940	1175	-35

Fiducial Mark Locations (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Left	240	903	240	23
Middle	609	899	616	22
Right	1021	897	1007	17

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC010001.B07	RC010001.B07	118	47		0.5	Al	*1,d*
LC080001.B07	RC080001.B07	3	8		0.5	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.B07	RE000001.B07	353	953		1.3	Al	*d*
LE000048.B07	RE000048.B07	-1	392		0.7	Al	
LE000049.B07	RE000049.B07	220	923	4	0.8	Al	*2,f*
LE000050.B07	RE000050.B07	921	-62		0.8	Al	*3*
LE000051.B07	RE000051.B07	200	-39		0.6	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.B07	RE000002.B07	21	793		0.7	TB	
LE000003.B07	RE000003.B07	48	883		0.8 x 0.9	TB	*4*
LE000004.B07	RE000004.B07	153	894		0.4	TB	
LE000005.B07	RE000005.B07	124	787		0.5	TB	
LE000006.B07	RE000006.B07	502	898		0.6	TB	
LE000007.B07	RE000007.B07	532	804		1.1	TB	
LE000008.B07	RE000008.B07	533	775		0.4	TB	
LE000009.B07	RE000009.B07	626	850		0.4	TB	
LE000010.B07	RE000010.B07	701	809		0.5	TB	
LE000011.B07	RE000011.B07	706	764		1.1	TB	
LE000012.B07	RE000012.B07	727	868		0.4	TB	
LE000013.B07	RE000013.B07	868	738		0.3	TB	
LE000014.B07	RE000014.B07	970	864		0.5	TB	
LE000015.B07	RE000015.B07	1016	779		0.7	TB	
LE000016.B07	RE000016.B07	1064	762		0.5	TB	
LE000017.B07	RE000017.B07	1098	794		0.5	TB	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000018.B07	RE000018.B07	1251	871		0.4	TB	
LE000019.B07	RE000019.B07	1186	626		0.5	TB	
LE000020.B07	RE000020.B07	844	631		0.5	TB	
LE000021.B07	RE000021.B07	845	627		0.5	TB	
LE000022.B07	RE000022.B07	788	675		0.5	TB	
LE000023.B07	RE000023.B07	736	636		0.4	TB	
LE000024.B07	RE000024.B07	698	715		0.9	TB	
LE000025.B07	RE000025.B07	318	731		0.5	TB	
LE000026.B07	RE000026.B07	63	437		0.5	TB	
LE000027.B07	RE000027.B07	46	475		0.4	TB	
LE000028.B07	RE000028.B07	41	509		0.4	TB	
LE000029.B07	RE000029.B07	43	556		0.4	TB	
LE000030.B07	RE000030.B07	164	577		0.5	TB	
LE000031.B07	RE000031.B07	182	552		0.7	TB	
LE000032.B07	RE000032.B07	280	305		0.2 x 0.5	TB	*4,5*
LE000033.B07	RE000033.B07	257	620		0.4	TB	*5*
LE000034.B07	RE000034.B07	282	555		0.4	TB	*6*
LE000035.B07	RE000035.B07	381	591		0.7	TB	
LE000036.B07	RE000036.B07	442	575		1.0	TB	*8*
LE000037.B07	RE000037.B07	402	463		0.5	TB	
LE000038.B07	RE000038.B07	478	408		0.5	TB	
LE000039.B07	RE000039.B07	555	606		0.4	TB	
LE000040.B07	RE000040.B07	599	441		0.4	TB	
LE000041.B07	RE000041.B07	700	542		0.4	TB	
LE000042.B07	RE000042.B07	801	504		0.5	TB	
LE000043.B07	RE000043.B07	985	529		0.3 x 0.5	TB	*4*
LE000044.B07	RE000044.B07	982	409		0.2 x 0.5	TB	*4*
LE000045.B07	RE000045.B07	1065	601		0.5	TB	
LE000046.B07	RE000046.B07	1071	575		0.4	TB	
LE000047.B07	RE000047.B07	1208	548		0.5	TB	
LE000052.B07	RE000052.B07	96	185		0.5	TB	
LE000053.B07	RE000053.B07	165	151		0.5	TB	
LE000054.B07	RE000054.B07	148	55		0.7	TB	
LE000055.B07	RE000055.B07	206	70		0.7	TB	*6,7*
LE000056.B07	RE000056.B07	250	179		0.6	TB	
LE000057.B07	RE000057.B07	439	295		0.4	TB	
LE000058.B07	RE000058.B07	616	202		0.5	TB	
LE000059.B07	RE000059.B07	693	235		0.4	TB	
LE000060.B07	RE000060.B07	753	73		0.5	TB	
LE000061.B07	RE000061.B07	952	104		0.8	TB	
LE000062.B07	RE000062.B07	1012	176		0.4	TB	
LE000063.B07	RE000063.B07	1040	248		0.6	TB	
LE000064.B07	RE000064.B07	1083	255		1.0	TB	
LE000065.B07	RE000065.B07	1123	93		0.4	TB	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

TB - Thermal Blanket (teflon, silver-inconel, binder, and paint)

1 - Teardropped shaped feature.

2 - Image taken at ~15° above normal of crater.
3 - Y cooridinate stored with image was 62 instead of -62.
4 - Elliptical feature.
5 - Unusual ring/halo pattern.
6 - No rings/halos.
7 - Wrong coordinates (X = 250, Y = 179) input with file.
8 - Penetration through velcro forming crater in aluminum blanket-support frame beneath.

OTHER PHOTODOCUMENTATION:

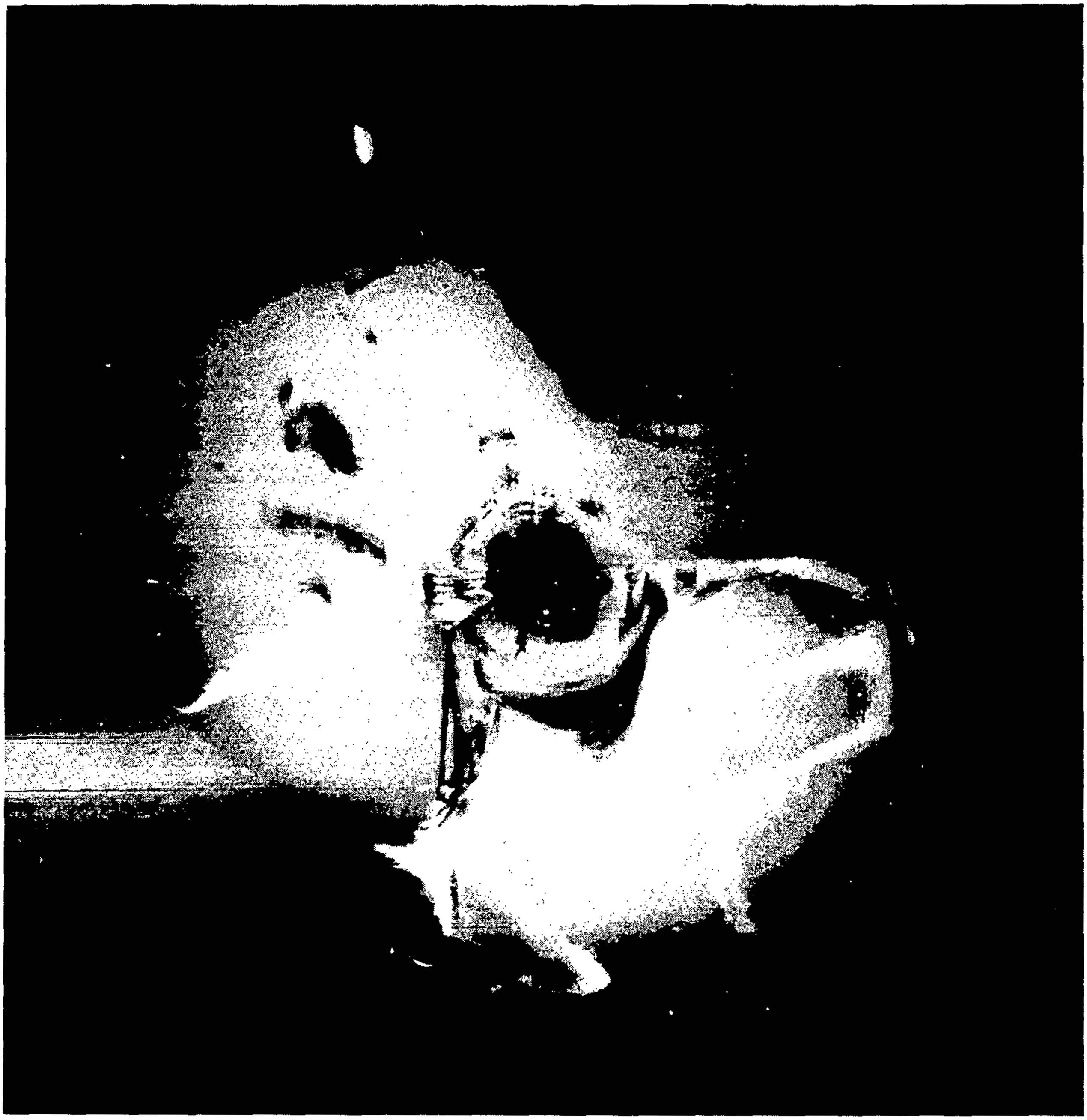
Pre-Flight - 84-07036
On-Orbit - S32-76-101
Pre-Deintegration - KSC-390C-1032.08, KSC-390C-1032.09, KSC-390C-1032.06
Post Deintegration - KSC-390C-2306.09, KSC-390C-2307.08
M&D SIG Photos - S90-43553, S90-43554 - Left 1/3 of Thermal Blanket; 1 front- and 1 back view.
S90-43556, S90-43557 - Center 1/3 of Thermal Blanket; 1 front- and 1 back view.
S90-43558, S90-43559 - Right 1/3 of Thermal Blanket; 1 front- and 1 back view.
S90-43555 - Tray in M&D SIG area.
S90-43434 - Impact with debris spray on upper tray flange.

ARCHIVED MATERIALS:

Clamps - B07C01, B07C03, B07C06, and B07C08
Thermal Blanket - (B07E00A) The U.S. third (minus the Materials SIG specimen) reside at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds (minus the Materials SIG grounding-strap specimen) is being archived at ESTEC in The Netherlands. Each blanket third was marked with two small crosses (see Fiducial Mark table above) for indexing and reconstruction purposes.

ACCOMPANYING FIGURES:

Figure B07-1. This is a view of one large impact feature on the B07 thermal blanket. A rounded delamination area surrounds the impact feature shown here, and the penetration hole is not spherical, possibly reflecting deformation of the Teflon surface. View measures approximately 10 cm across.



LDEF LOCATION:	**B08**
EXPERIMENT IDENTIFICATION:	**S0001**
EXPERIMENT TITLE:	**SPACE DEBRIS IMPACT EXPERIMENT**
PRINCIPAL INVESTIGATOR:	**D. HUMES** **493 NASA LANGLEY RESEARCH CENTER** **HAMPTON, VIRGINIA 23665**
	A0056 **EXPOSURE TO SPACE RADIATION OF HIGH-PERFORMANCE INFRARED MULTI-LAYER FILTERS AND MATERIALS TECHNOLOGY EXPERIMENTS** **J. SEELEY** **CENTER FOR APPLIED OPTICS** **UNIVERSITY OF ALABAMA** **HUNTSVILLE, ALABAMA 35899**
	A0147 **PASSIVE EXPOSURE OF EARTH RADIATION BUDGET EXPERIMENT COMPONENTS** **J. HICKEY** **THE EPPLEY LABORATORY, INC.** **12 SHEFFIELD AVENUE** **NEWPORT, RHODE ISLAND 02840**

SUMMARY OF OBSERVATIONS

Bay B08 was 3"-deep (7.6 cm) passive experiment-tray which contained three experiments: S0001, A0056, and A0147. Two-thirds of the experiment-tray was occupied by S0001, one-sixth of contained experiment A0056, and the final one-sixth of the experiment-tray was filled by experiment A0147.

For S0001, this tray was one of 25 whole or partial trays which make up the Space Debris Impact Experiment. The S0001 experiment hardware consists of aluminum plates (6061-T6 aluminum) each 0.1875" (4.8 mm) thick. The plates have a thin chromic anodized coating on both sides and a coat of Chemglaze Z306 black paint on the back side for thermal control. The S0001 experiment occupied 19 3"-deep peripheral trays, two 3"-deep end corner trays on the Earth-facing end of LDEF, and one 3"-deep end corner tray on the space-facing end of LDEF. Additionally, several partial tray locations (like this one) on the periphery of LDEF were utilized and integrated with other experiments. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

Along with this experiment-tray, experiments A0056 and A0147 occupied one-quarter of a center tray on the Earth-facing end of LDEF. Experiment A0056 consisted of 20 high-performance infrared filter samples mounted in BS.L93 chromic anodized aluminum alloy circular mounts, and held in place by lead washers. The filter substrates included germanium, silicon, zinc selenide, aluminum oxide, thallium bromo-iodide, cadmium

telluride, calcium fluoride, and quartz. The coatings, which were multi-layers on the substrates, included lead telluride, germanium, zinc sulfite, zinc selenide, cadmium selenide, thallium bromo-iodide, silicon monoxide, and lead fluoride. In addition, this experiment included spacecraft materials samples with various surface finishes and thermal paints. These included Aeroweb aluminum alloy honeycomb (2.0-3/16-07-5056-T), 2024-T81 aluminum alloy face skins for the honeycomb panel, DHP 282 beryllium copper retaining springs, PV 100 and S13 GLO white thermal control paints, and two carbon-fiber-reinforced plastics: GY70 fiber code 87 resin prepreg and A-S fiber code 69 resin prepreg. The experiment was mounted flush with the experiment-tray flanges.

Experiment A0147 consisted of solar channel components of the Earth radiation budget radiometer. These included thermopiles, interference filters, and fused silica optical windows. The samples were mounted in 6061-T6 aluminum alloy panels. The cavity detector aluminum panel was anodized (MIL-A-86250, Type III, Class I) with a nickel acetate sealer. The channels in the cavity detector were sulfuric anodized with a nickel sulfide inorganic black dye. The thermopiles were painted black with Chemglaze Z-306 paint and 9924 primer. The remaining aluminum base panels and sample supports were painted with Chemglaze Z-302 white paint. The anodized aluminum experiment walls were left unpainted.

After the experiments A0056 and A0147 were deintegrated from the experiment-tray, the experiment-tray was left intact with experiment S0001 and returned to the S0001 Principal Investigator.

Experiment-tray B08 provided the best example on LDEF of secondary ejecta and collateral effects of impacts. Several impacts occurred into the sides and edges of sample holders on experiment A0056, leaving secondary ejecta spray patterns on the base plate, experiment samples, and experiment-tray walls. Several impacts also occurred in the leading-edge facing wall of experiment A0147. These impacts left secondary ejecta spray patterns on the white painted aluminum base plate. In addition, impacts into the painted aluminum created spall zones in the paint around the crater and had rings (in the paint around the crater) with a diameter more than 20 times the crater diameter. The impacts into crystalline specimens, like glass, created deep well-like depressions in the center of the impact features with a surrounding outer spallation region, sometimes accompanied by substrate fracture. The well-like depression diameters were recorded as the crater diameters. Impacts into aluminum were typical of craters produced in aluminum during laboratory hypervelocity impact tests.

On experiment-tray B08, the M&D SIG survey visually identified a total of 787 impact features on all associated experiment-tray surfaces. These surfaces included the tray flanges and walls, the experiment-tray clamps, and the experiment-tray clamp bolts. On the aluminum experimental surfaces, 708 impacts were located. Of these, 647 of the impacts were <0.5 mm in diameter (four were photodocumented as they were considered to be of interest), 58 were between 0.5 mm and 1.0 mm in diameter, two were between 1.0 mm and 1.5 mm in diameter, and one was between 1.5 mm and 2.0 mm in diameter. Of the 46 impacts on the experiment-tray flanges and walls, 40 were <0.5 mm in diameter and were not photodocumented, 5 were between 0.5 mm and 1.0 mm in diameter, and one was between 1.0 mm and 1.5 mm in diameter. On the experiment-tray clamps, 30 of the 33 impacts identified were <0.5 mm in diameter, and three were between 0.5 mm and 1.0 mm in diameter.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	30	40	647	717
≥0.5 mm	3	6	61	70
TOTALS	33	46	708	787

The largest impact features identified on tray B08 were (1) an ~1.7 mm diameter crater located on the S0001 aluminum tray surface, (2) an ~1.0 mm diameter crater on the experiment-tray flange, and (3) an ~0.8 mm crater on an experiment-tray clamp.

Several other features were imaged which are of particular interest. One impact occurred into the side of the A0056 experiment base plate (in the crack between the experiment base plate and the experiment-tray wall) and created an ejecta spray pattern onto the inside of the experiment-tray wall across from the crater. This impact occurred ~19 mm down the side of the base plate (toward the bottom of the experiment-tray); the opening between the experiment base plate and the experiment-tray wall was ~5 mm. This crater could not be photodocumented until the experiment was deintegrated from the experiment-tray. At that time, the crater was photodocumented. This crater is one of only a few found on LDEF which could be geometrically shown to have been produced at a highly oblique angle. Although the ~0.8 mm diameter crater must have been produced by a highly oblique impact, the crater was nearly round and the ejecta which was sprayed onto the tray wall travelled nearly perpendicular to the surface in which the crater was produced, *i.e.* along the normal to the crater. In addition, there was an ejecta spray pattern on one side of the crater. Also, although it may be unrelated to the impact, there was a gouge-like feature in the aluminum surface near the crater which lined up radially with the center of the crater.

Another impact of interest on A0056 was into a glass-like clear experiment sample. The impact occurred on the sample near the edge of the sample holder. The impact crater was ~1.0 mm in diameter, with a spallation diameter of ~5.5 mm, and two large cracks emanated from the crater to the opposite side of the sample, apparently breaking the specimen into three pieces. Although other samples had impact craters of ~1.0 mm in diameter with large spallation diameters and small fractures, this was the only sample which showed evidence of complete fracture of the substrate.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 22, 1990 while the experiment-tray was mounted on the spacecraft. This inspection identified fifteen features which might be destroyed by attachment of the experiment-tray cover and seven features which would be destroyed by emplacement in the experiment-tray rotator. These latter impact features were estimated to be ~0.5 mm in diameter, except for one which was ~1.5 mm in diameter. These features were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the most interesting feature within the experiment-tray cover area, the cover gasket was cut in one location to prevent it from coming into contact with this feature and to provide a stand-off for the experiment-tray cover and the tray flanges. One feature each was identified on clamps C01, C04, C05, and C07. Two features each were identified on clamps C03, C06, and C08.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations or spallation features on the front or back of the 0.0625" (1.6 mm) thick experiment-tray flanges. However, there were two bulges identified on the back of the tray flanges. The bulge on the bottom flange did not correspond to an impact feature. However, the bulge on the left flange corresponded to an ~1.5 mm diameter crater on the front of the flange. Because it would be destroyed when placed in the experiment-tray rotator, this crater was photodocumented using M&D SIG System #3.

DOCUMENTATION:

The detailed examination and photodocumentation of tray B08 was conducted on March 14 and 15, 1990 in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #1. The bolts, clamps and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC060001.B08	RC060001.B08	40	12		0.6	Al	
LC080001.B08	RC080001.B08	2	73		0.8	Al	
LC080002.B08	RC080002.B08	31	55		0.7	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.B08	RE000001.B08	728	8		1.5	Al	*1,h*
LE000001.B08	RE000001.B08	399	963		0.8	Al	*2*
LE000002.B08	RE000002.B08	405	974		0.5	Al	
LE000017.B08	RE000017.B08	552	946	15	1.0	Al	*3,f*
LE000059.B08	RE000059.B08	0	51		0.5	Al	
LE000060.B08	RE000060.B08	485	-31		0.9	Al	
LE000061.B08	RE000061.B08	578	-25		0.6	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000003.B08	RE000003.B08	246	891		0.5 x 0.8	Al	*4*
LE000004.B08	RE000004.B08	334	851		0.7	Al	*4*
LE000005.B08	RE000005.B08	250	849		0.6	Al	*4*
LE000006.B08	RE000006.B08	483	905		0.5	Al	*4*
LE000007.B08	RE000007.B08	577	828		0.6	Al	*4*
LE000008.B08	RE000008.B08	757	917		0.9	Al	*4*
LE000009.B08	RE000009.B08	1250	884		0.7	Al	*5*
LE000010.B08	RE000010.B08	1220	874		0.5 x 0.6, 1.8	Al	*5,6,7,b*
LE000011.B08	RE000011.B08	908	840		0.7 x 1.0	Al	*5*
LE000012.B08	RE000012.B08	949	802		0.5	Al	*5,8,e*
LE000013.B08	RE000013.B08	911	788		0.5	Al	*5*
LE000014.B08	RE000014.B08	1127	788		0.5	Al	*5*
LE000015.B08	RE000015.B08	972	782		0.1	Al	*5,9,e*
LE000016.B08	RE000016.B08	840	848		0.6	Al	*10,g*
LE000018.B08	RE000018.B08	1196	728		0.6 x 0.7	Al	*5,11,12*
LE000019.B08	RE000019.B08	915	693		0.6	Al	*5,12*
LE000020.B08	RE000020.B08	1043	631		1.0	Al	*5*
LE000021.B08	RE000021.B08	1131	660		0.5	Al	*5,11*
LE000022.B08	RE000022.B08	1237	621		0.8	Al	*5,13,14*
LE000023.B08	RE000023.B08	1166	602		0.5	ND	*5,15*
LE000024.B08	RE000024.B08	1020	625		1.0, 5.5	SiO_2	*5,16,17,m*
LE000025.B08	RE000025.B08	882	512		1.0, 3.4	SiO_2	*5,17,m*
LE000026.B08	RE000026.B08	1062	492		0.6	Al	*5*
LE000027.B08	RE000027.B08	1041	362		0.5, 0.8	Al	*6,7,18,b*
LE000028.B08	RE000028.B08	1182	290		0.4, 1.0, 7.3	Al	*6,7,18,19,b*
LE000029.B08	RE000029.B08	1081	207		0.7	Al	*14,18*
LE000030.B08	RE000030.B08	818	708		0.7	Al	*4*
LE000031.B08	RE000031.B08	734	625		0.5	Al	*4*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000032.B08	RE000032.B08	453	621		0.5	Al	*4*
LE000033.B08	RE000033.B08	442	553		0.7	Al	*4*
LE000034.B08	RE000034.B08	546	583		0.5	Al	*4*
LE000035.B08	RE000035.B08	678	470		0.8	Al	*4,20*
LE000036.B08	RE000036.B08	673	394		0.5 x 0.6	Al	*4*
LE000037.B08	RE000037.B08	762	439		0.6	Al	*4*
LE000038.B08	RE000038.B08	597	405		0.6	Al	*4*
LE000039.B08	RE000039.B08	484	330		0.6	Al	*4*
LE000040.B08	RE000040.B08	553	349		0.6	Al	*4*
LE000041.B08	RE000041.B08	556	328		0.6	Al	*4*
LE000042.B08	RE000042.B08	550	326		0.7	Al	*4*
LE000043.B08	RE000043.B08	740	321		0.9	Al	*4*
LE000044.B08	RE000044.B08	528	258		0.5	Al	*4*
LE000045.B08	RE000045.B08	175	675		0.7	Al	*4*
LE000046.B08	RE000046.B08	174	765		0.6	Al	*4*
LE000047.B08	RE000047.B08	44	681		0.5	Al	*4*
LE000048.B08	RE000048.B08	42	644		0.7	Al	*4*
LE000049.B08	RE000049.B08	318	542		0.6	Al	*4*
LE000050.B08	RE000050.B08	361	375		0.7	Al	*4*
LE000051.B08	RE000051.B08	238	419		1.3	Al	*4*
LE000052.B08	RE000052.B08	182	285		0.6	Al	*4*
LE000053.B08	RE000053.B08	181	215		0.5	Al	*4*
LE000054.B08	RE000054.B08	122	242		0.7	Al	*4*
LE000055.B08	RE000055.B08	1060	463	ND	0.5	Al	*18,21,22,e,f*
LE000056.B08	RE000056.B08	1120	463	ND	0.9	Al	*18,21,22,e,f*
LE000057.B08	RE000057.B08	867	438	ND	0.6	Al	*18,21,23,e,f*
LE000058.B08	RE000058.B08	848	237	ND	0.6	Al	*18,21,24,e,f*
LE000062.B08	RE000062.B08	23	91		0.7	Al	*4*
LE000063.B08	RE000063.B08	44	147		1.3	Al	*4*
LE000064.B08	RE000064.B08	109	160		0.7	Al	*4*
LE000065.B08	RE000065.B08	243	14		0.7	Al	*4*
LE000066.B08	RE000066.B08	443	119		1.7	Al	*4*
LE000067.B08	RE000067.B08	635	129		0.6	Al	*4*
LE000068.B08	RE000068.B08	658	169		0.9	Al	*4*
LE000069.B08	RE000069.B08	896	119		0.5, 1.4, 3.0	Al	*6,7,18,19,b*
LE000070.B08	RE000070.B08	971	29		0.6, 1.7, 2.4	Al	*6,7,18,19,b*
AE010001.B08	BE010001.B08	1242	496	15	0.8	Al	*5,25,26,d,e*
LE010001.B08	RE010001.B08	1242	496	15	0.8	Al	*5,25,d,e*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined
IRF - Infrared filter sample.

1 - This impact caused the bulge in the left tray flange. The image was stored on M&D SIG A-Team optical disk #5, side A, and was taken using M&D SIG System #3; all other tray flange and experiment surface images were taken using M&D SIG System #2. This feature was not included in the Feature Summary chart.

2 - This feature was stored on M&D SIG A-Team optical disk #6, side A and was taken using M&D SIG System #2. This is a different feature than that mentioned in comment #1.

3 - Image taken at 40° above normal to crater.
4 - Impact into experiment S0001.
5 - Impact into experiment A0056.
6 - Diameter listed after comma is diameter of spallation zone.
7 - Impact into white painted aluminum.
8 - Impact into sample holder, ejecta spray onto aluminum base plate.
9 - Impact into sample holder, ejecta spray onto infrared filter sample.
10 - Impact into bottom experiment-tray frame between experiments S0001 and A0056.
11 - Impact into aluminum strap holding materials samples.
12 - Wrong experiment (S0001) input into image file.
13 - Impact into edge of aluminum base plate.
14 - Image taken at 30° above normal to crater.
15 - Impact into materials sample (metal) which is first of three sample squares.
16 - Impact into glass sample which apparently fractured sample into three pieces.
17 - Diameter listed after comma is diameter of fracture zone.
18 - Impact into experiment A0147.
19 - Diameter listed after second comma is diameter of outer ring.
20 - Wrong coordinates (X = 678, Y = 511) input into image file.
21 - Impact into experiment wall, ejecta spray onto white painted aluminum base plate.
22 - Image taken at 38° above normal to crater.
23 - Image taken at 38° above normal to crater and 20° left of normal to crater.
24 - Image taken at 60° left of normal to crater.
25 - Highly oblique impact (but circular crater) into side of aluminum base plate which caused ejecta spray onto experiment-tray wall opposite the impact crater (not seen in image) and ejecta spray onto surface surrounding crater. Could not be imaged while experiment-tray was integrated; image taken after experiment was deintegrated from experiment-tray.
26 - Lower magnification view to show gouge leading to crater.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-294/7
On-Orbit - S32-76-26
Pre-Deintegration - KSC-390C-1031.03, KSC-390C-1031.04, KSC-390C-1031.11
Post Deintegration - KSC-390C-1931.01
M&D SIG Photos - S90-43491 - Feature #57 ejecta spray pattern,
S90-43492 - Ejecta spray pattern from "Too Small" impact into A0147 tray wall,
S90-43493 - Feature #56 ejecta spray pattern,
S90-43494 - Ejecta spray pattern from "Too Small" impact into A0147 tray wall,
S90-43495 - Feature #12 ejecta spray pattern,
S90-43496 - Ejecta spray pattern from impact A0056 aluminum sample holder; impact could not be imaged,
S90-43497 - Ejecta spray pattern from Feature #E010001 (see comment 25 above) into experiment-tray wall,
S90-43498 - Feature #25,

ARCHIVED MATERIALS:

Clamps - B08C04, B08C05, B08C06, and B08C08
Clamp Bolts - B08S01, B08S02, B08S03, B08S04, B08S05, B08S06, B08S07, B08S08, B08S09
Clamp Shims - B08H04
Other - (B08E00A) - White painted aluminum base plate from experiment A0147

ACCOMPANYING FIGURES:

Figure B08-1. This is a view of one large impact feature on an optical surface from tray B08. Large radial cracks extend across the entire surface of the sample, and the "crater" consists of finely-shattered material. View measures approximately 2 cm across.

LDEF LOCATION: B09
TRAY IDENTIFICATION: S0010
EXPERIMENT TITLE: EXPOSURE OF SPACECRAFT COATINGS
PRINCIPAL INVESTIGATOR: W. SLEMP
MS 183
NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

A0134
SPACE EXPOSURE OF COMPOSITE MATERIALS FOR LARGE SPACE STRUCTURES
W. SLEMP
MS 183
NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay B09 contained a 6"-deep (15.2 cm), integrated, passive experiment tray that housed two experiments (S0010 and A0134) designed to study the effects of space exposure on composite and spacecraft materials.

The S0010 experiment was designed to measure the effects of both the Shuttle-induced environment and the space radiation environment (*e.g.*, contamination, atomic oxygen, solar ultraviolet, and thermal cycling) on selected sets of spacecraft thermal control coatings. The S0010 experiment occupied approximately 60 percent of the external exposure area of tray B09. An experiment exposure control canister (EECC) occupied 33 percent of the tray and 100 coatings and witness specimens utilize the remaining 27 percent. The external coatings and witness specimens were exposed during launch operations and orbit insertion and were exposed during retrieval and post-orbital handling of the LDEF vehicle. The EECC contained 104 coating specimens and was programmed prior to launch to be exposed for 10 months. A detailed list of thermal control coatings is presented in Table 8, page 56

The A0134 experiment was designed to evaluate the effects of the Low Earth Orbit (LEO) space environment on composite materials. The effects of atomic oxygen, solar ultraviolet, and thermal cycling will be compared to the effects of thermal cycling alone. The A0134 experiment occupies approximately 40 percent of the front and rear exposure area of B09. Groups of precut tensile and flexure specimens (both 0.005" [0.13 mm] and 0.003" [0.08 mm] ply thicknesses of resin-impregnated material) and composite panels were clamped to an aluminum mounting plate. One set of specimens was in the RAM-facing direction and the other set was on the back of the mounting plate shielded from UV or direct atomic oxygen exposure. Polymeric and resin films (*e.g.*, Mylar, Kapton, P-1700 polysulfone, and FEP Teflon) will be used to provide additional data on the behavior of polymers in space. A detailed list of composite specimens is presented in Table 8, page 56 of *The Long Duration Exposure Facility (LDEF), Mission 1 Experiments* handbook (NASA SP-473; Clark, Kinard, Carter, and Jones, eds., 1984).

Impact features residing in the various aluminum hardware associated with each of the two experiments on B09 were typical of hypervelocity impacts into aluminum produced under laboratory conditions. Impacts into the composite material of both experiments S0010 and A0134 were sometimes difficult to see due to the darkness and texture of the material. When impact features were found, distinguishable craters or penetration diameters were difficult to determine because of the fibrous consistency of the graphite/epoxy composites.

The M&D SIG survey identified a total of 808 features on the B09 experiment tray including the experiment-tray bolts, clamps, shims and flanges. Of the 808 impacts found, 724 features did not meet the >0.5 mm diameter criteria for impact craters so these features were not imaged. The only known locations of the "Too Smalls" were 52 located on the experiment-tray clamps and bolts. Of the remaining 86 imaged features, nine were located on the experiment-tray flanges and ranged in diameter from 0.5 mm to 1.3 mm with one imaged impact being < 0.5 mm. Four were located on the experiment-tray clamps C02, C05, C06, and C08 and ranged in diameter from 0.7 mm to 1.8 mm. The 73 remaining impacts were located on the two experimental surfaces S0010 and A0134. Thirty-three of these impacts were located on experiment S0010 and ranged in diameter from 0.3 mm to 1.2 mm, with one feature being a penetration which was 0.5 mm in diameter. Forty of these impacts were located on experiment A0134 and ranged in diameter from 0.2 mm to 1.6 mm, with six being penetrations ranging in diameter from 0.3 mm to 1.1 mm.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			4	4
>0.3 mm			6	6
<0.5 mm	52			724*
>0.5 mm	4	8	62	74
TOTALS	56			808

* - The locations of the "Too Smalls" were not documented.

The largest impact features identified on tray B09 were (1) a circular impact ~1.3 mm located on the experimental-tray flange, (2) a circular impact ~1.6 mm in diameter located on the A0134 experimental surface, (3) a circular impact ~1.2 mm in diameter located on the S0010 experimental surface, and (4) a circular impact ~1.8 mm in diameter located on tray clamp C02. There were many impacts into the Al on all surfaces of the tray that possessed red debris sprays.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft and the M&D SIG identified ten features that might be damaged by the placement of the experiment-tray cover and five additional features that could be damaged or destroyed by the placement of the experiment tray within the experiment tray stand. The latter impact features were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the more interesting feature within the experiment-tray cover area, the cover gasket was cut in three locations to prevent it from coming into contact with the features and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations of the 0.0625" (1.6 mm) thick experiment-tray flanges and no bulges or spalls on the back of the tray flanges.

DOCUMENTATION:

On March 15, 1990 the B09 experiment tray was inspected and photodocumented in the vertical position by M&D SIG System #1 and impact coordinates were determined using Coordinate Registration System #3. The detailed inspection of the clamps and bolts was performed on March 13, 1990, using M&D SIG System #3 and impact coordinates were determined using a metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	58	958	59	-16
Center	617	959	616	-17
Far Right	1175	956	1174	-16

Impact Features Imaged on Experimental-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC020001.B09	RC020001.B09	113	11		1.8	Al	*3*
LC050001.B09	RC050001.B09	58	29		1.4	Al	
LC060001.B09	RC060001.B09	92	43		0.7	Al	
LC080001.B09	RC080001.B09	14	94		0.8	Al	

Impact Features Imaged on Experimental-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.B09	RE000001.B09	12	963		0.8	Al	
LE000066.B09	RE000066.B09	264	-24		0.5	Al	*k*
LE000067.B09	RE000067.B09	689	-8		0.5	Al	*4*
LE000068.B09	RE000068.B09	1057	-25		1.0	Al	
LE000075.B09	RE000075.B09	160	233		0.6	Al	*5,g*
LE000076.B09	RE000076.B09	3	249	15	0.8	Al	*6,g*
LE000077.B09	RE000077.B09	2	156	35	1.3	Al	*7,g*
LE000078.B09	RE000078.B09	248	6	28	0.7	Al	*5,8,f*
LE000082.B09	RE000082.B09	1248	743		1.1	Al	*4*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.B09	RE000002.B09	101	880		0.7	Al	*1*
LE000003.B09	RE000003.B09	38	831		0.5	Al	*1*
LE000004.B09	RE000004.B09	56	842		0.6	Al	*1*
LE000005.B09	RE000005.B09	265	863		1.0	Al	*1*
LE000006.B09	RE000006.B09	336	831		0.6	Al	*1*
LE000007.B09	RE000007.B09	348	839		0.5	Al	*1*
LE000008.B09	RE000008.B09	248	758		0.9	Al	*1*
LE000009.B09	RE000009.B09	274	739		0.6	Al	*1*
LE000010.B09	RE000010.B09	315	739		0.6	Al	*1,8*
LE000011.B09	RE000011.B09	406	740		1.1	Al	*1*
LE000012.B09	RE000012.B09	345	715		0.6	Al	*1*
LE000013.B09	RE000013.B09	92	723		0.8	Al	*1*
LE000014.B09	RE000014.B09	89	681		0.8	Al	*1,9*
LE000015.B09	RE000015.B09	356	680		1.2	Al	*1*
LE000016.B09	RE000016.B09	316	664		0.6	Al	*1,10*
LE000017.B09	RE000017.B09	118	660		0.7	Al	*1*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000018.B09	RE000018.B09	420	910		0.7	Al	2,11
LE000019.B09	RE000019.B09	511	916		1.6	Al	2
LE000020.B09	RE000020.B09	440	829		0.8	Al	2,11
LE000021.B09	RE000021.B09	731	799		1.1	composite	2,12
LE000022.B09	RE000022.B09	535	702		0.5	Al	2
LE000023.B09	RE000023.B09	580	687		1.2	Al	2
LE000024.B09	RE000024.B09	575	708		0.5	Al	2
LE000025.B09	RE000025.B09	534	660		0.7	Al	2
LE000026.B09	RE000026.B09	472	577		0.7	Al	2
LE000027.B09	RE000027.B09	608	575		0.5	Al	2
LE000028.B09	RE000028.B09	846	877		0.9	Al	2
LE000029.B09	RE000029.B09	943	903		0.5	composite	2
LE000030.B09	RE000030.B09	1047	903		0.6	Al	2
LE000031.B09	RE000031.B09	1104	891		0.5	Al	2
LE000032.B09	RE000032.B09	1165	912		0.7	Al	2
LE000033.B09	RE000033.B09	1177	924		0.6	Al	2
LE000034.B09	RE000034.B09	1188	922		0.6	composite	2
LE000035.B09	RE000035.B09	1151	898		1.0	ND	2
LE000036.B09	RE000036.B09	1217	864		0.6	Al	2,11
LE000037.B09	RE000037.B09	1075	864		0.7	Al	2
LE000038.B09	RE000038.B09	1071	796		0.6	composite	2
LE000039.B09	RE000039.B09	941	855		0.6	composite	2,14
AE000039.B09	BE000039.B09	941	855		0.6	composite	2,13
LE000040.B09	RE000040.B09	986	780		0.6	composite	2
LE000041.B09	RE000041.B09	1034	563		0.7	Al	2
LE000042.B09	RE000042.B09	920	586		0.2	composite	2
LE000043.B09	RE000043.B09	920	603		0.3	Graphite/Epoxy	2
LE000044.B09	RE000044.B09	1182	594		0.3	composite	2,16
LE000045.B09	RE000045.B09	1146	582		0.7	composite	2
LE000046.B09	RE000046.B09	1208	563		0.6	Al	2
LE000047.B09	RE000047.B09	1152	461		0.5	Al	2
LE000048.B09	RE000048.B09	1228	314		0.8	Al	2
LE000049.B09	RE000049.B09	1178	332		0.2	composite	2,17
LE000050.B09	RE000050.B09	1203	223		1.6	Al	2
LE000051.B09	RE000051.B09	763	495		0.7	Al	1
LE000052.B09	RE000052.B09	698	454		0.4 x 0.6	Al	1
LE000053.B09	RE000053.B09	674	336		0.3	composite	1,18
LE000054.B09	RE000054.B09	627	260		0.6	Al	1
LE000055.B09	RE000055.B09	598	319		0.7	Al	1
LE000056.B09	RE000056.B09	571	323		0.9	specimen?	1,19
LE000057.B09	RE000057.B09	427	468		1.1	Al	1
LE000058.B09	RE000058.B09	361	471		0.6	Al	1
LE000059.B09	RE000059.B09	353	622		0.9	Al	1,20
LE000060.B09	RE000060.B09	237	399		1.0	Al	1
LE000061.B09	RE000061.B09	186	336		0.6	Al	1
LE000062.B09	RE000062.B09	846	115		1.2	Al	2
LE000063.B09	RE000063.B09	862	115		0.8	Al	2
LE000064.B09	RE000064.B09	1032	150		0.3	composite	2,21
LE000065.B09	RE000065.B09	690	208		0.4	specimen?	1
LE000069.B09	RE000069.B09	460	124		0.5	specimen?	1,22
LE000070.B09	RE000070.B09	494	120		0.3	specimen?	1
LE000071.B09	RE000071.B09	861	115		0.6	Al	2,23

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000072.B09	RE000072.B09	1052	64		0.9	Al	2,24
AE000072.B09	BE000072.B09	1052	64		0.7	Al	2
LE000073.B09	RE000073.B09	1139	76		0.9	Al	2
LE000074.B09	RE000074.B09	1182	87		0.5 x 0.6	composite	2
LE000079.B09	RE000079.B09	69	624		0.6	Al	1
LE000080.B09	RE000080.B09	137	531		0.6	Al	1
LE000081.B09	RE000081.B09	213	523		0.8	Al	1
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	n
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	o
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	p
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	q

ND - Not Determined

1 - Features located on experiment S0010.
2 - Features located on experiment A0134.
3 - Wrong coordinates (X = 0, Y = 0) input into image file.
4 - Image taken 10° off normal of crater.
5 - No Z coordinate stored with image.
6 - Image taken 30° to left, and 30 degrees above normal.
7 - Image taken 20° to left, and 30° above normal.
8 - Red debris spray pattern at 12:30.
9 - Crater rim flattened prior to documentation.
10 - Red debris spray pattern at 6:30.
11 - Illumination with left gooseneck only.
12 - Spallation along fiber bundles.
13 - Second image of feature LE000039.B09, not documented why image was taken.
14 - Penetration through the composite.
15 - Diameter given is of central pit, damage area over 1.0 mm.
16 - Outer penetration diameter D=0.4 mm.
17 - Spall zone 1.2 mm, entered into the computer incorrectly as the diameter of the central pit.
18 - Oblique spall zone 0.7 mm x 1.8 mm.
19 - Melt zone approximately 1.5 mm x 2.0 mm.
20 - Crater lip is broken and pulled back.
21 - Almost penetrated completely through composite.
22 - Outer penetration diameter D=1.1 mm.
23 - High crater lip.
24 - Wrong crater imaged on Left and Right versions LE000072.B09 and RE000072.B09.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-84-07027
On-Orbit - S32-76-01
Pre-deintegration - KSC-390C-1030.10, KSC-390C-1030.12, KSC-390C-1031.01
Post Deintegration - KSC-390C-1913.09, KSC-390C-1916.05, KSC-390C-1916.06, KSC-390C-1916.07
M&D SIG Photos - None

ARCHIVED MATERIALS

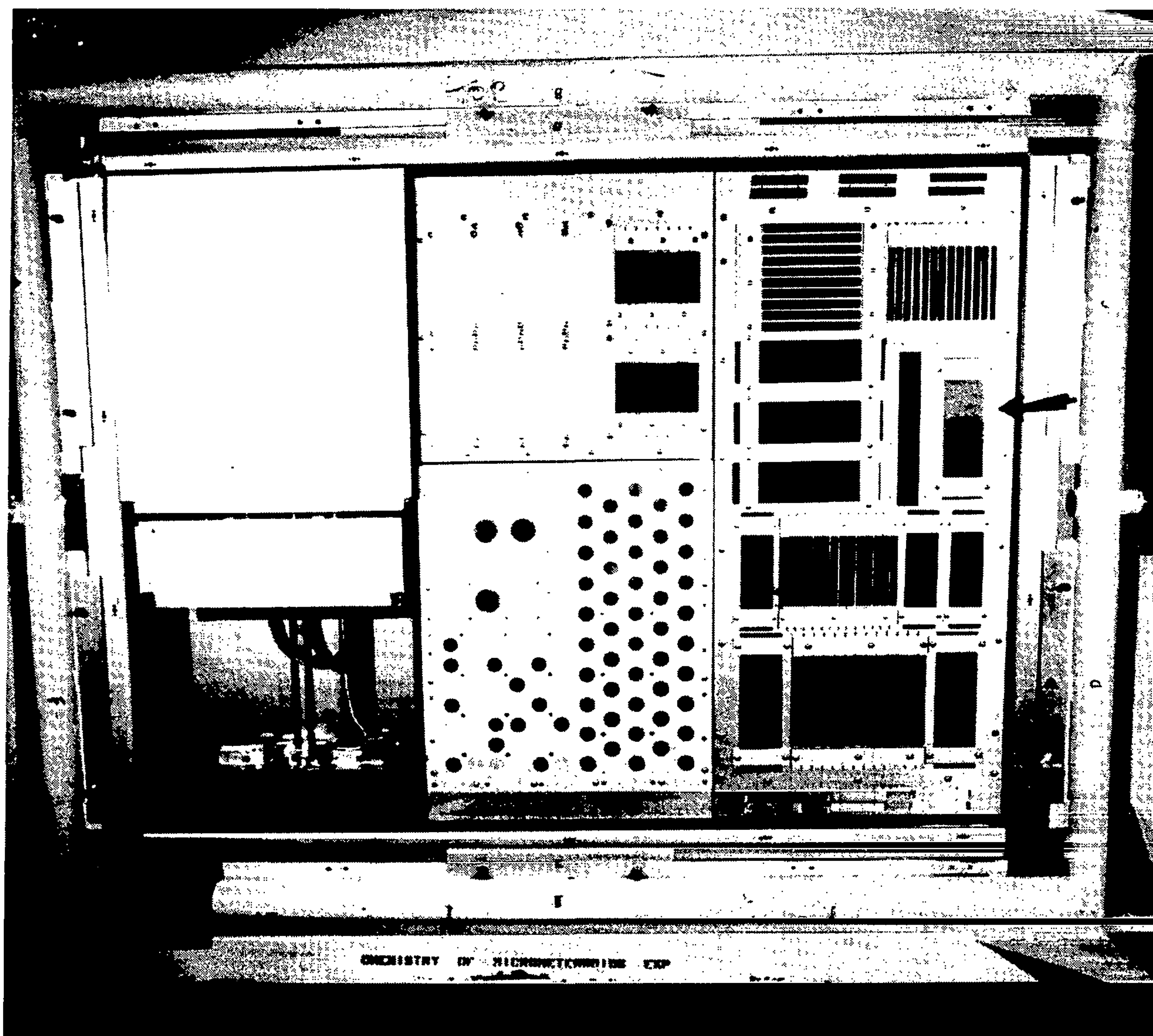
Clamps -B09C02, B09C05, B09C06, and B09C08
Clamp Bolts - B09S01C, B09S03A, B09S04C
Clamp Shims - B09H08

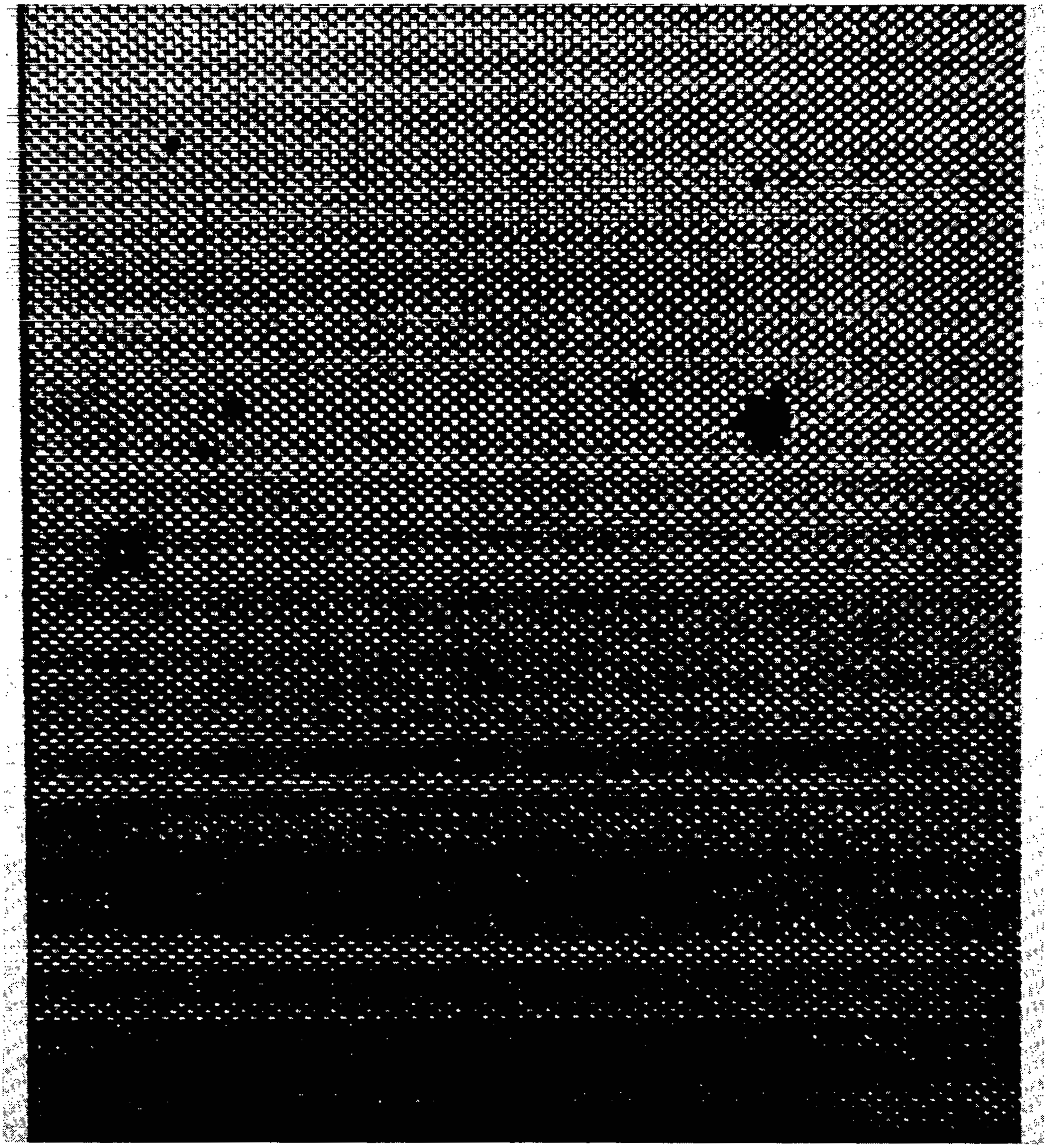
ACCOMPANYING FIGURES:

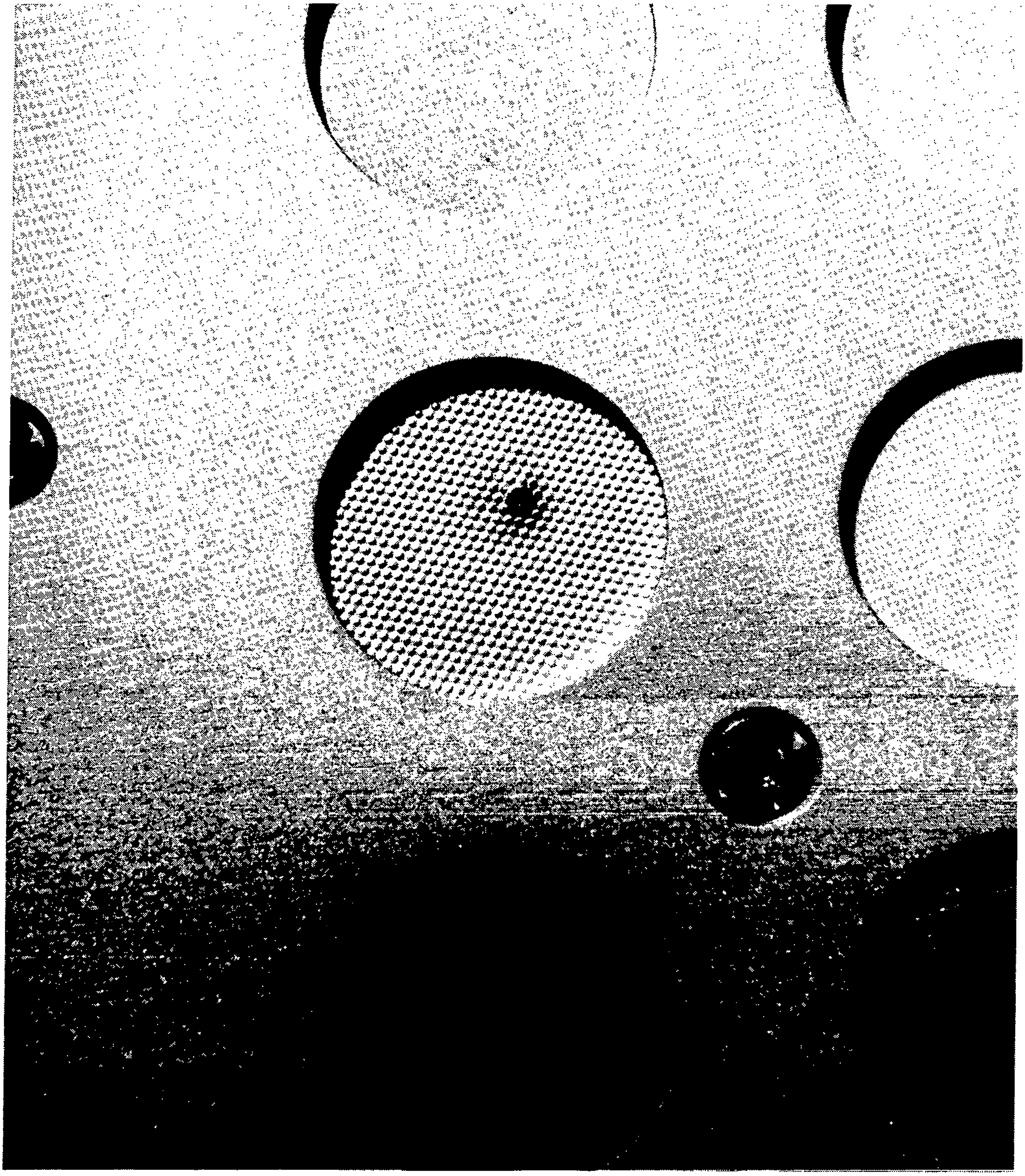
Figure B09-1 - This post-deintegration view shows the front of the entire B09 experiment tray. The arrow on the right indicates the area shown in Figure B09-2, and the arrow on the left locates Figure B09-3.

Figure B09-2. This view shows impact features in the fabric material of Tray B09. View measures approximately 4 cm across.

Figure B09-3. This view illustrates impact features in two materials from the bottom of Tray B09. View measures approximately 4 cm across.







LDEF LOCATION: B10
EXPERIMENT IDENTIFICATION: S1005
EXPERIMENT TITLE: TRANSVERSE FLAT-PLATE HEAT PIPE EXPERIMENT
PRINCIPAL INVESTIGATOR: J. OWEN
NASA MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA 35812

SUMMARY OF OBSERVATIONS

Bay B10 occupied a 12"-deep (30.5 cm) experiment tray containing the active Transverse Flat-Plate Heat Pipe Experiment. The experimental surface was unique on LDEF from a meteoroid and debris point of view. Three transverse flat-plate heat pipes that spanned the length of the tray and were ~7" (17.8 cm) wide were separated from each other by two 1.5" (3.8 cm) wide aluminum, T-shaped support channels that were covered with a multi-layer thermal blanket (MTB). The blanket consisted of 8-10 layers of ~5 lm thick aluminized Mylar, and the individual layers were separated with Dacron netting and wrapped with an outer covering of teflon-coated fiberglass cloth (beta cloth). The three heat pipes were separated from the experiment-tray flanges by two 6" (15.2) wide aluminum support channels that were also covered with the multi-layer thermal blanket. The heat pipe surfaces were composed of an aluminum honeycomb structure that had a 5 mill (~125 lm) thick silvered (~2000 Å) teflon film bonded to the exterior aluminum sheet with 1-2 mills of an acrylic adhesive. The heat pipe surface accounted for ~60% of the total experimental surface area, while the multi-layer thermal blanket accounted for the remaining surface area. The teflon surface on the heat pipes was an opaque white color when it returned from orbit, as compared to an initial mirror-like finish before launch.

Impacts into the beta cloth blanket material were similar, morphologically, to features identified in fibrous composite materials. The major observable impact-induced damage was rupture of the glass fibers. A small amount of material appeared to have been vaporized, but the frayed and pliable edges of the fibers around the penetration hole often could be found overlapping the hole (Figure 2.B - 16). It was not possible to see below the beta cloth layer of this type of MTB. Because the yarn diameter and weave spacing was on the order of a few hundred microns, it was difficult to visually detect very small features in this surface. A total of seven features were found on thermal blanket surfaces, the smallest of which had a diameter of ~0.2 mm, or approximately the width of one fiber bundle. This compares to a total of 293 small features (teflon hole diameter <0.5 mm) identified on the heat-pipe surfaces. Impacts into the bonded teflon/aluminum surfaces produced a melt hole and a shock delamination zone in the teflon, and a small central crater in the aluminum surface in many cases. In all discussions below, the diameter values for features on these surfaces refer to the hole in the teflon surface, not the diameter of the small crater (when it was present) in the aluminum. Hole diameters were measured using the standard procedures for thin film penetrations described in Section 2.B. A feature threshold diameter value of 0.5 mm was used as an imaging criterion for the heat pipe surfaces.

The mechanism of impact-feature production on the heat pipe surfaces on Tray B10 was very different from the hole production (penetration) mechanism in true thin films; the structure was never actually penetrated in the case of the heat-pipe surfaces. The production of the hole in the teflon film was caused both by the initial energy imparted to the film by the impactor's penetration through it, and by the blowback of plasma and debris from the impact into the aluminum surface immediately below the film.

A total of 414 features were visually identified on the entire tray surface of B10. Twenty-six craters <0.5 mm in diameter, and six that were >0.5 mm in diameter were found on the 0.19" thick, chromic anodized 6061-T6 aluminum tray clamps. A total of five features, all <0.5 mm, were found in the 0.25", 303 stainless steel, hex-head clamp bolts, including one in a washer associated with bolt C04A. Twenty-three features with diameters <0.5 mm, and eight with diameters >0.5 mm were found on the experiment-tray flanges. A total of 298 features with hole diameters <0.5 mm were found on the experimental surfaces, including five that were in the

multi-layer thermal blanket. There were also 48 features with hole diameters >0.5 mm in the experimental surfaces, two of which were in the beta cloth. A total of 71 features were imaged, including eight large features on tray clamps, two on clamp bolts (including the one on bolt C04A washer), eight large features on the experiment-tray flanges, and 53 features on the experimental surfaces, seven of which were in the beta cloth thermal blanket material. Five out of the seven features identified in the beta cloth were <0.5 mm, but were imaged because of the scarcity of impacts found in this material. One image on the experimental surface (LE000049.B10) includes two features >0.5 mm in diameter in very close proximity to each other. Because of the multi-layer construction of the experimental surfaces, a compromise focal setting was used in order to provide the best image possible of the top most penetration hole in the teflon surface and the frequently occurring, smaller associated crater in the aluminum sheet metal below. In most cases the entire impact induced delamination zone is included in the image.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	31	23	298	352
>0.5 mm	6	8	48	62
TOTALS	37	31	346	414

The largest impact features identified were (1) an ~1.2 mm diameter crater clamp C02, (2) an ~1.0 mm diameter feature on the experiment-tray flange, (3) two oblique features in the beta-cloth thermal blanket material which left holes in the top layer of the blanket measuring ~0.3 x 0.7 mm and ~0.3 x 0.6 mm, respectively, and (4) two features on the teflon/aluminum surface which had teflon hole diameters of ~2.5 mm, delamination zones of ~4.5 mm, and craters in the aluminum measuring ~0.7 mm in diameter. In addition, there were five features with teflon hole diameters between ~2.0 and ~2.5 mm. The most interesting feature was a ~1.5 mm diameter impact on a heat pipe that possessed some apparent impactor residue within the feature.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft. This inspection identified thirteen features which might be destroyed by attachment of the experiment-tray cover and four features which would be destroyed by emplacement in the experiment-tray rotator. The latter impact features were not examined or photodocumented, nor were they included in the numerical summary given above. Although four features were located in the area where the experiment-tray cover was to be place, it was not required to alter the gasket material. Eleven features were found on experiment-tray clamps C01, C02, C04, and C05.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick aluminum experiment-tray flanges. There were several deep scratches, unrelated to impact phenomena, on the backsides of the tray flanges.

DOCUMENTATION:

Tray B10 was inspected in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #2 on March 1, 1990. Tray clamps, bolts and shims were also inspected on March 9, 1990 using M&D SIG System #3. A non-standard zero reference point was used to document the locations of features on this tray. To avoid application of a fiducial mark (per the PI's request), a small crater located on the left experiment-tray flange at X = 0, Y = 8 in the standard reference system, was used as the zero reference point.

Thus, all coordinates listed below, and in the image files, were measured from this non-standard reference point.

Bolt-Hole Registration (mm)

	TOP X	TOP Y	BOTTOM X	BOTTOM Y
Far Left	55	940	55	-33
Center	614	940	613	-33
Far Right	1172	941	1171	-33

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC010001.B10	RC010001.B10	4	46		0.7	Al	
LC020001.B10	RC020001.B10	45	6		0.4	Al	
LC040001.B10	RC040001.B10	42	52		1.2	Al	
LC040001.B10	RC040001.B10	11	96		0.8	Al	
LC050001.B10	RC050001.B10	113	3		0.6	Al	
LC060001.B10	RC060001.B10	4	32		0.5	Al	
LC080001.B10	RC080001.B10	47	20		0.8	Al	
LC080001.B10	RC080001.B10	28	43		0.4	Al	
LS010001.B10	RS010001.B10	0	0		0.4	stainless steel	
LS040001.B10	RS040001.B10	0	8		0.2	stainless steel	*1*

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.B10	RE000001.B10	-18	784		0.5	Al	
LE000002.B10	RE000002.B10	244	920		0.7	Al	*2*
LE000019.B10	RE000019.B10	814	960		1.0	Al	
LE000020.B10	RE000020.B10	837	954		0.8	Al	
LE000021.B10	RE000021.B10	1017	959		0.9	Al	
LE000037.B10	RE000037.B10	-11	362		0.7	Al	
LE000057.B10	RE000057.B10	679	-32		0.6	Al	
LE000058.B10	RE000058.B10	529	-46		0.5	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000003.B10	RE000003.B10	410	837		0.4	MTB	*3*
LE000004.B10	RE000004.B10	55	676		0.5 x 0.7	HP	*c*
LE000005.B10	RE000005.B10	94	708		0.5	HP	*c*
LE000006.B10	RE000006.B10	144	687		0.6	HP	*c*
LE000007.B10	RE000007.B10	242	688		0.7	HP	*3,c*
LE000008.B10	RE000008.B10	298	699		0.5	HP	*c*
LE000009.B10	RE000009.B10	542	711		1.0	HP	*c*
LE000010.B10	RE000010.B10	537	638		1.2	HP	*c*
LE000011.B10	RE000011.B10	591	731		1.7 x 2.5	HP	*c*
LE000012.B10	RE000012.B10	704	722		0.18	HP	*4,c*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000013.B10	RE000013.B10	720	624		2.2	HP	*c*
LE000014.B10	RE000014.B10	810	735		1.1	HP	*c*
LE000015.B10	RE000015.B10	876	730		1.1	HP	*c*
LE000016.B10	RE000016.B10	1085	604		0.7	HP	*c*
LE000017.B10	RE000017.B10	1193	619		0.5	HP	*c*
LE000018.B10	RE000018.B10	1218	828		0.2	MTB	
LE000022.B10	RE000022.B10	206	507		0.6	HP	*c*
LE000023.B10	RE000023.B10	210	503		2.5	HP	*c*
LE000024.B10	RE000024.B10	277	526		1.0	HP	*c*
LE000025.B10	RE000025.B10	329	518		1.9	HP	*c*
LE000026.B10	RE000026.B10	475	456		0.7	HP	*c*
LE000027.B10	RE000027.B10	696	513		1.1	HP	*c*
LE000028.B10	RE000028.B10	714	528		1.3	HP	*c*
LE000029.B10	RE000029.B10	736	533		1.5	HP	*c,k*
LE000030.B10	RE000030.B10	734	455		2.5	HP	*c*
LE000031.B10	RE000031.B10	746	431		0.6 x 1.0	HP	*c*
LE000032.B10	RE000032.B10	859	497		1.8	HP	*c*
LE000033.B10	RE000033.B10	957	381		1.5	HP	*c*
LE000034.B10	RE000034.B10	1103	501		1.2	HP	*c*
LE000035.B10	RE000035.B10	1125	497		0.7	HP	*c*
LE000036.B10	RE000036.B10	695	343		0.4	MTB	
LE000038.B10	RE000038.B10	70	291		1.0	HP	*c*
LE000039.B10	RE000039.B10	89	322		0.7	HP	*c*
LE000040.B10	RE000040.B10	138	269		1.8	HP	*c*
LE000041.B10	RE000041.B10	330	234		2.0	HP	*c*
LE000042.B10	RE000042.B10	414	302		1.1	HP	*c*
LE000043.B10	RE000043.B10	425	306		0.7	HP	*c*
LE000044.B10	RE000044.B10	578	264		0.8	HP	*c*
LE000045.B10	RE000045.B10	621	189		1.0	HP	*c*
LE000046.B10	RE000046.B10	622	237		0.5	HP	*5,c*
LE000047.B10	RE000047.B10	719	211		0.7	HP	*c*
LE000048.B10	RE000048.B10	774	256		0.5	HP	*c*
LE000049.B10	RE000049.B10	801	329		0.5, 0.6	HP	*6,c*
LE000050.B10	RE000050.B10	861	236		1.6	HP	*c*
LE000051.B10	RE000051.B10	1031	326		0.6	HP	*7,c*
LE000052.B10	RE000052.B10	1118	219		0.5	HP	*c*
LE000053.B10	RE000053.B10	1178	253		1.8	HP	*c*
LE000054.B10	RE000054.B10	837	80		0.4	MTB	
LE000055.B10	RE000055.B10	821	82		0.3	MTB	
LE000056.B10	RE000056.B10	825	168		2.0	HP	*c*
LE000059.B10	RE000059.B10	548	90		0.3 x 0.7	MTB	
LE000060.B10	RE000060.B10	439	98		0.3 x 0.6	MTB	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

MTB - Multilayer Thermal Blanket, beta cloth surface.
HP - Heat Pipe, silvered teflon/aluminum surface.

1 - Feature located on stainless steel washer.
2 - Feature located on curve of experiment-tray flange; image taken at ~45° angle.

3 - Incorrect coordinates (X = 419, Y = 837) entered with image file.
4 - Irregular shaped feature.
5 - A second, small crater is included in the field of view.
6 - Two features on the edge of the heat pipe.
7 - Feature located on the corner edge of heat pipe; feature imaged at ~45° from normal of crater.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-84-583
On-Orbit - S32-78-076
Pre-Deintegration - KSC-390C-1028.12, KSC-390C-1029.01, KSC-390C-1029.09
Post Deintegration - KSC-390C-1038.03, KSC-390C-1038.04, KSC-390C-1038.05, KSC-390C-1413.08
M&D SIG Photos - None

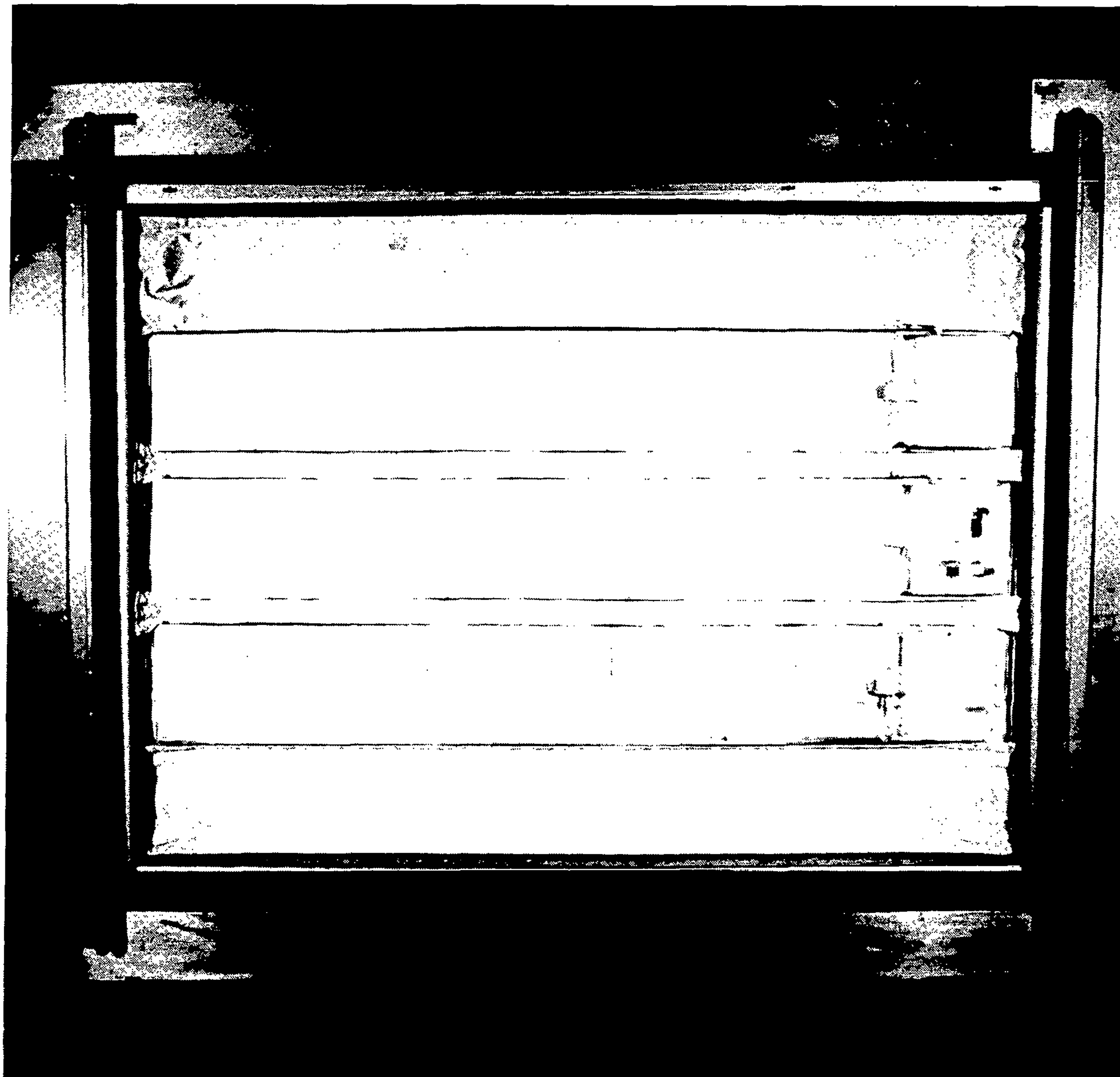
ARCHIVED MATERIALS:

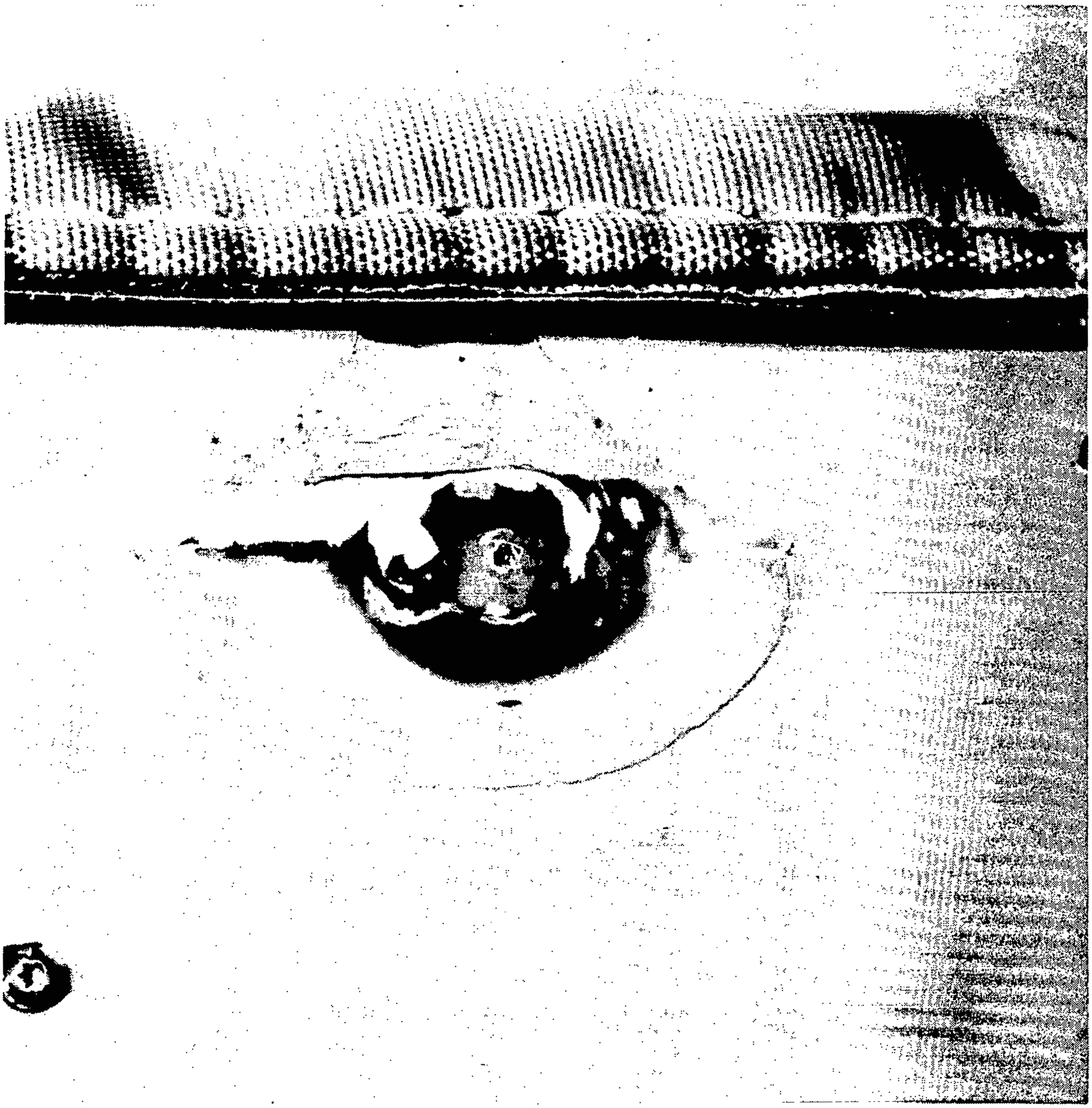
Clamps - B10C01, B10C04, B10C06 and B10C07
Clamp Bolts - B10S03C, B10S04A, B10S04C, B10S06B and B10S08BS

ACCOMPANYING FIGURES:

Figure B10-1. This post-deintegration view shows the front of the entire B10 experiment tray.

Figure B10-2. This is a view of a large impact with spall across one of the heat-pipe covers. View measures approximately 4 cm across.





LDEF LOCATION: B11
EXPERIMENT IDENTIFICATION: S0001
EXPERIMENT TITLE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES
493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay B11 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays that were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 230 features on the B11 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of these, 170 features from all surfaces were found to be less than the 0.5 mm photodocumentation threshold. Fifty features were photodocumented from the aluminum collector surfaces, 54 of which were between 0.5 mm and 1.0 mm in diameter, five features that were between 1.0 mm and 1.5 mm in diameter, and one feature that was >1.0 mm in diameter. Eight features were documented on the experimental-tray flanges and ranged in diameter from 0.5 mm to 1.1 mm and one feature was documented on experiment-tray clamp C06 and was ~0.5 mm in diameter. All features exhibited characteristics typical of craters formed in aluminum during laboratory hypervelocity impact experiments.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	25			170*
>0.5 mm	2	9	49	60
TOTALS	27			230

* - The locations of the "Too Smalls" were not documented.

The largest impact feature found on this tray measured ~1.8 mm in diameter located on the experimental-tray surface; there were seven other impact features >1.0 mm in diameter.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft and identified two features that might be damaged by the placement of the experiment-tray cover. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges or spallation features on the 0.0625" (1.6 mm) thick experiment-tray flanges or backside.

DOCUMENTATION:

Examination and photodocumentation of Tray B11 was conducted on March 8, 1990 in the vertical position utilizing M&D SIG System #2. The bolts, clamps and shims associated with this tray were scanned with M&D SIG System #2. The coordinates for all features associated with this tray were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC060001.B11	RC060001.B11		15	32	0.5	Al	*1*

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.B11	RE000001.B11	308	-10		0.5	Al	
LE000002.B11	RE000002.B11	1225	-13		0.5	Al	
LE000053.B11	RE000053.B11	1290	635		0.6	Al	
LE000054.B11	RE000054.B11	1280	210		1.0	Al	
LE000055.B11	RE000055.B11	48	0	70	1.1	Al	*4,f*
LE000056.B11	RE000056.B11	225	0	50	0.7	Al	*4,f*
LE000057.B11	RE000057.B11	0	280	1	0.5	Al	*4,f*
LE000058.B11	RE000058.B11	0	350	45	0.5	Al	*4,f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000003.B11	RE000003.B11	205	150		1.2 x 1.4	Al	*2*
LE000004.B11	RE000004.B11	25	30		0.7	Al	
LE000005.B11	RE000005.B11	120	180		0.5 x 0.6	Al	
LE000006.B11	RE000006.B11	80	420		0.5	Al	
LE000007.B11	RE000007.B11	240	430		1.8	Al	
LE000008.B11	RE000008.B11	230	320		0.5 x 0.8	Al	
LE000009.B11	RE000009.B11	340	375		0.6	Al	
LE000010.B11	RE000010.B11	305	445		0.6	Al	
LE000011.B11	RE000011.B11	365	450		0.6	Al	
LE000012.B11	RE000012.B11	418	60		1.0	Al	
LE000013.B11	RE000013.B11	550	75		0.7	Al	
LE000014.B11	RE000014.B11	405	124		0.7	Al	
LE000015.B11	RE000015.B11	425	178		0.7	Al	
LE000016.B11	RE000016.B11	610	415		0.5	Al	
LE000017.B11	RE000017.B11	375	475		0.5	Al	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000018.B11	RE000018.B11	878	50		0.7	Al	
LE000019.B11	RE000019.B11	740	190		0.7	Al	
LE000020.B11	RE000020.B11	725	200		0.4 x 0.5	Al	
LE000021.B11	RE000021.B11	638	255		0.6	Al	
LE000022.B11	RE000022.B11	745	395		0.8	Al	
LE000023.B11	RE000023.B11	715	420		0.7 x 0.8	Al	*d*
LE000024.B11	RE000024.B11	930	420		0.9	Al	
LE000025.B11	RE000025.B11	1138	105		0.7	Al	*3*
LE000026.B11	RE000026.B11	988	275		0.6	Al	
LE000027.B11	RE000027.B11	965	300		0.5	Al	
LE000028.B11	RE000028.B11	1022	335		0.6	Al	
LE000029.B11	RE000029.B11	1100	335		0.5	Al	
LE000030.B11	RE000030.B11	938	455		0.9	Al	*w*
LE000031.B11	RE000031.B11	1045	488		0.6	Al	*w*
LE000032.B11	RE000032.B11	85	958		0.8	Al	*x*
LE000033.B11	RE000033.B11	180	825		0.9	Al	*x*
LE000034.B11	RE000034.B11	200	715		0.5	Al	*x*
LE000035.B11	RE000035.B11	270	685		0.9	Al	*x*
LE000036.B11	RE000036.B11	280	625		0.5	Al	*x*
LE000037.B11	RE000037.B11	190	545		0.9	Al	*x*
LE000038.B11	RE000038.B11	78	510		0.8	Al	*x*
LE000039.B11	RE000039.B11	530	775		1.0	Al	*x*
LE000040.B11	RE000040.B11	410	580		0.7	Al	*x*
LE000041.B11	RE000041.B11	575	510		0.7	Al	*x*
LE000042.B11	RE000042.B11	550	495		0.5	Al	*w*
LE000043.B11	RE000043.B11	768	840		1.1	Al	
LE000044.B11	RE000044.B11	730	720		0.7	Al	*2*
LE000045.B11	RE000045.B11	740	565		0.6	Al	
LE000046.B11	RE000046.B11	860	520		0.6	Al	*2*
LE000047.B11	RE000047.B11	885	540		0.7	Al	
LE000048.B11	RE000048.B11	980	868		0.6	Al	
LE000049.B11	RE000049.B11	1068	745		1.3	Al	
LE000050.B11	RE000050.B11	1150	664		0.7	Al	
LE000051.B11	RE000051.B11	1190	585		0.8	Al	
LE000052.B11	RE000052.B11	1115	525		0.6	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - An incorrect image label was entered into the optical disk and image.
2 - Incorrect coordinates were entered into the optical disk and images.
3 - Impact crater rim appears to be incomplete.
4 - Image is rotated 60° clockwise.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-78-38
Pre-Deintegration - KSC-390C-1028.09, KSC-390C-1028.10, 1028.07
Post Deintegration - KSC-390C-2159.11
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - B11C04, B11C06, B11C07 and B11C08
Clamp Bolts - B11S01A and B11S07A

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION: B12
EXPERIMENT IDENTIFICATION: A0201
EXPERIMENT TITLE: INTERPLANETARY DUST EXPERIMENT
PRINCIPAL INVESTIGATOR: G. WEINBURG

INSTITUTE FOR SPACE SCIENCES AND TECHNOLOGY
GAINESVILLE, FLORIDA 32609

SUMMARY OF OBSERVATIONS

Bay B12 accommodated a 6"-deep (15.2 cm) tray, one third of which was occupied by the metal-oxide-silicon (MOS), capacitor-type detectors of the A0201 Interplanetary Dust Experiment. The remaining two thirds of the tray housed the power (batteries) and data-storage (tape recorder) components associated with this, as well as the other five bay locations on LDEF (C03, C09, D06, G10, and H11) occupied in whole or part by this experiment. The objective of the MOS detectors was to obtain mass and velocity information on the particles impinging upon their surfaces. Two varieties of detectors totaling ~1 m^2 of exposed surface area were flown on A0201; sixty percent of the detector surfaces possessed an oxide coating of 0.4 μm thick, while the remaining 40 percent had a 1.0 μm thick oxide coating. Each one-third tray typically contained 80 MOS detectors and one Sun sensor.

Features examined within the originally smooth metal-oxide-silicon surfaces exhibited somewhat complex morphologies. Generally, these impacts exhibited a deep central pit; the diameter of this pit was utilized by the M&D SIG A-Team for the 0.5 mm threshold criteria. Surrounding the central pits were spallation zones possessing diameters on the order of 1.25 to 3 times that of the central pit. Fractures or cracks radiating from the central pit/spall zone were commonly found in association with the larger impacts into the amorphous metal-oxide-silicon material. All other features on this tray occurred into aluminum substrates and exhibited morphologic characteristics typical laboratory hypervelocity impacts into similar materials.

The M&D SIG survey identified a total of 370 features on the B12 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the experiment- and related surfaces. Of these, 336 features from all surfaces were <0.5 mm in diameter, while 34 were >0.5 mm in diameter. All features >0.5 mm in diameter were photodocumented as were four features <0.5 mm in diameter from the detector surfaces that exhibited unusual morphologies. Image LE000034.B12 documents some debris on the experiment-tray flange that was associated with an impact into the edge of clamp C06 (Feature LC060002.B12). Initially, a feature-protection device was placed over this debris, but was later removed because it prevented the experiment-tray cover from properly interfacing with the experiment-tray flanges. Two other features were photodocumented from clamps C01 and C02; a total of 17 features <0.5 mm in diameter were found on the eight clamps holding the experiment tray into Bay B12. Twenty-one features found on the extremely smooth MOS detector, six features located on the aluminum rings and mounting plates associated with the detector surfaces, and four impacts on the experiment-tray flanges were photodocument; all were >0.5 mm in diameter. A feature protection device was placed over Feature LE000035.B12. This device was not removed from the tray flange prior to packaging and shipment of the tray to the home institution of the Principal Investigator.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	17			336*
>0.5 mm	3	4	26	34
TOTALS	20			370

* - The locations of the "Too Smalls" were not documented.

The largest impact features identified on tray B12 were (1) an ~2.2 mm feature in MOS detector Cell 35; an ~4 mm diameter spall zone and radiating fractures were associated with this feature. A large piece of the wafer in Cell 35 was missing as a result of this impact, (2) an oblique ~1.2 x 0.7 mm feature on the experiment-tray flange, and (3) an ~1.1 mm diameter crater on the edge of clamp C06.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection of Bay B12 was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft. This survey identified seven features that might be damaged by the emplacement of the experiment-tray cover and two additional features that could be damaged or destroyed by clamping the experiment tray into the rotator. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in two locations to provide a stand-off distance between the experiment-tray cover and experiment-tray flanges and to prevent these features from becoming deformed or contaminated. One feature each was identified on clamps C01, C02, and C06. The feature on clamp C06 was located on the edge of the clamp and debris from this impact could be seen on the experiment-tray flange directly adjacent to this clamp.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick experiment-tray flanges. A feature protection device was placed over the debris pattern located on the bottom tray flange (see Pre-Deintegration, above) while the tray was in the battery removal area. An additional feature protection device was also placed over an ~1.1 mm diameter impact on the upper tray flange.

DOCUMENTATION:

Examination and photodocumentation of tray B12 was conducted on March 9, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #2. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #1; the coordinates for features residing on the clamps were measured with a metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	58	958	53	-17
Center	616	956	613	-18
Far Right	1174	954	1171	-20

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC010001.B12	RC010001.B12	96	21		0.6	Al	
LC020001.B12	RC020001.B12	55	4		0.6	Al	
LC060001.B12	RC060001.B12	108	49		1.1	Al	*1*
LE000034.B12	RE000034.B12	575	-27		ND	Al	*2*

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.B12	RE000001.B12	1016	967		0.6	Al	
LE000025.B12	RE000025.B12	1266	305		1.2 x 0.7	Al	
LE000026.B12	RE000026.B12	-18	436		0.5	Al	
LE000034.B12	RE000034.B12	575	-27		ND	Al	*2*
LE000035.B12	RE000035.B12	908	978		1.1	Al	*3,6*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.B12	RE000002.B12	251	926		0.4	MOS	*b*
LE000003.B12	RE000003.B12	70	843		0.5	MOS	*b*
LE000004.B12	RE000004.B12	464	850		0.5	MOS	
LE000005.B12	RE000005.B12	537	818		1.8	MOS	
LE000006.B12	RE000006.B12	1199	765		0.5	MOS	
LE000007.B12	RE000007.B12	234	638		0.8	MOS	*b*
LE000008.B12	RE000008.B12	172	637		0.6	MOS	*b*
LE000009.B12	RE000009.B12	17	604		0.7	Al	
LE000010.B12	RE000010.B12	316	586		2.2	MOS	*b,m*
LE000011.B12	RE000011.B12	371	536		0.7	MOS	
LE000012.B12	RE000012.B12	107	484		0.6	MOS	
LE000013.B12	RE000013.B12	402	321		0.6	Al	
LE000014.B12	RE000014.B12	577	516		1.0	MOS	
LE000015.B12	RE000015.B12	653	534		0.4	MOS	*b*
LE000016.B12	RE000016.B12	661	412		0.8	MOS	
LE000017.B12	RE000017.B12	528	328		0.6	MOS	
LE000018.B12	RE000018.B12	976	616		0.5 x 0.7	MOS	*4,b*
LE000019.B12	RE000019.B12	934	720		0.6	MOS	*b*
LE000020.B12	RE000020.B12	911	487		0.6	MOS	*b*
LE000021.B12	RE000021.B12	1170	469		0.6	MOS	*b*
LE000022.B12	RE000022.B12	867	416		0.9	MOS	*b*
LE000023.B12	RE000023.B12	894	289		0.6	MOS	*b*
LE000024.B12	RE000024.B12	891	202		0.6	MOS	*b*
LE000027.B12	RE000027.B12	296	130		0.3	MOS	*b*
LE000028.B12	RE000028.B12	327	0		1.0	Al	*h*
LE000029.B12	RE000029.B12	248	1		1.0	Al	*b*
LE000030.B12	RE000030.B12	451	178		0.6	MOS	
LE000031.B12	RE000031.B12	791	108		0.9	MOS	
LE000032.B12	RE000032.B12	857	128		1.2 x 1.0	Al	*5,b*
LE000033.B12	RE000033.B12	828	55		1.0	Al	*5,b*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined
MOS - Metal-oxide-silicon detector wafers.

1 - Impact feature located on side of clamp.

2 - Image of debris on tray flange associated with Feature LC060001.B12.
3 - Images taken through lexan cover of feature protection device.
4 - Incorrect coordinates (X = 934, Y = 720) entered with image.
5 - Impact into painted aluminum battery cover.
6 - Feature protection device placed over impact feature.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-84-7004
On-Orbit - S32-78-26
Pre-Deintegration - KSC-390C-1069.04, KSC-390C-1069.05, KSC-390C-1069.12
Post Deintegration - KSC-390C-1737.09, KSC-390C-1744.01, KSC-390C-1739.09, KSC-390C-1739.10, KSC-390C-1739.11
M&D SIG Photos - None

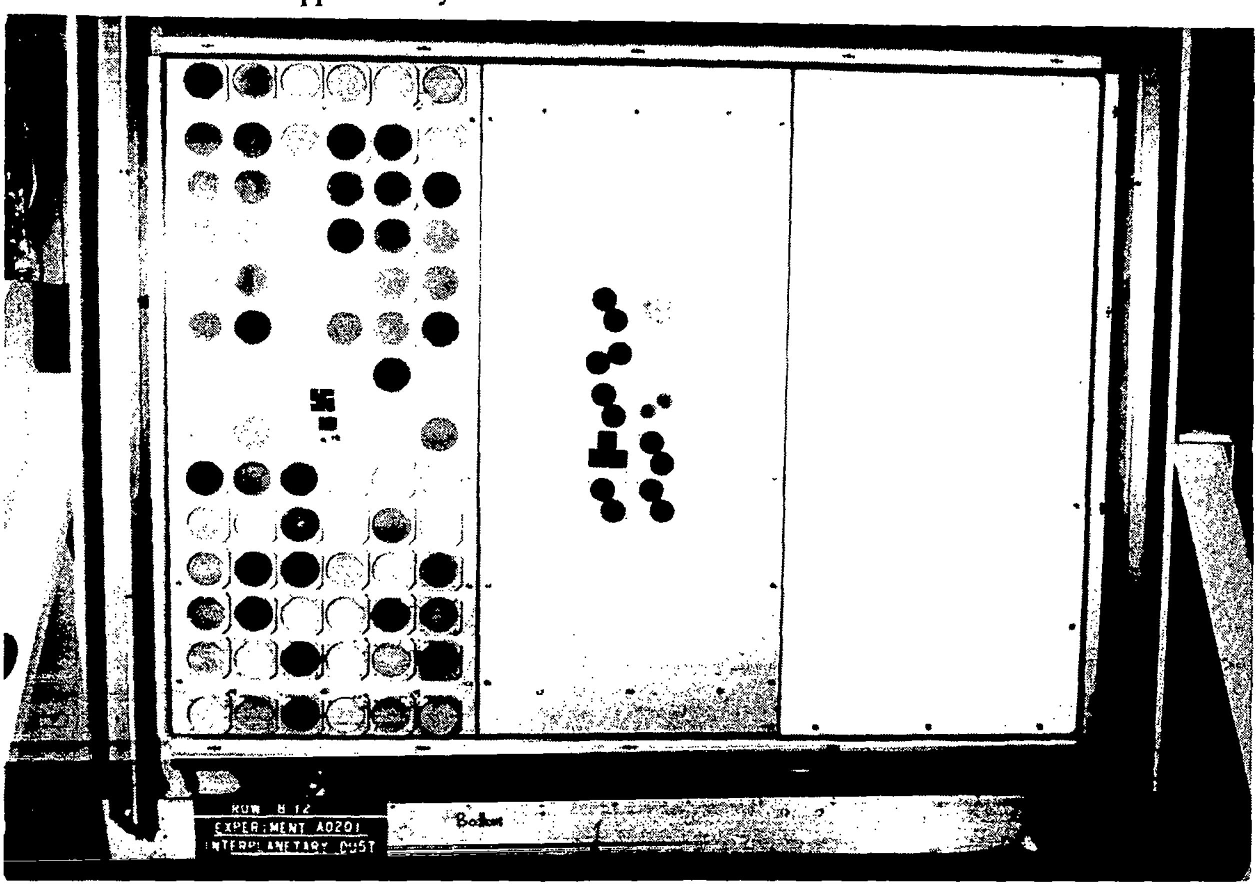
ARCHIVED MATERIALS:

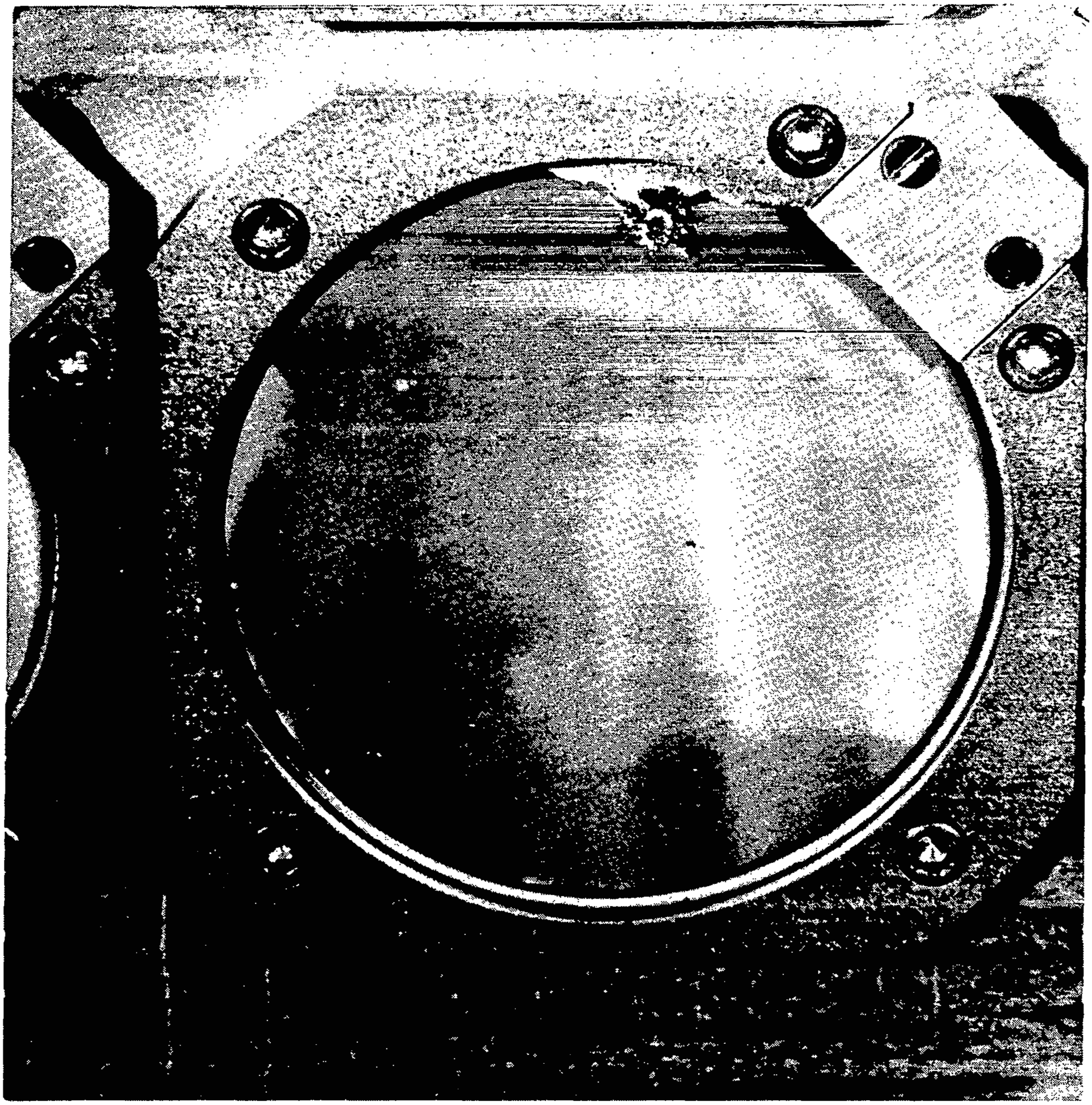
Clamps - B12C01, B12C02, B12C05, and B12C06
Clamp Bolts - B12S03B

ACCOMPANYING FIGURES:

Figure B12-1. This post-deintegration view shows the front of the entire B12 experiment tray.

Figure B12-2. This is a view of impact feature #17, with associated shattering, onto a MOS detector. View measures approximately 9 cm across.





LDEF LOCATION: C01
EXPERIMENT IDENTIFICATION: GRAPPLE
PRINCIPAL INVESTIGATOR: SPAR

LDEF PROJECT OFFICE
NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay C01 was occupied by one of the two grapple fixtures occupying 6"-deep (15.2 cm) trays which were aboard the LDEF spacecraft. This particular grapple fixture was totally passive and was used for both the deployment and retrieval of the LDEF spacecraft. The grapple fixture was attached *via* a base (abutment) plate to a 0.125" (3.2 mm) thick 6061-T6 aluminum plate which resided in the bottom of the tray. A small (~1" [2.5 cm] in diameter) teflon button was located at the end of each grapple pin.

The M&D SIG survey identified a total of 151 features on the C01 grapple tray including the grapple-tray bolts, clamps, shims, and flanges, as well as the tray's base plate and grapple fixture. Of these, 68 were found on the aluminum plate at the bottom of the tray, the clamps, or the grapple fixture. Fifty nine of these features were <0.5 mm in diameter (54 from the base plate or grapple fixture and nine on the various clamps), nine were between 0.5 and 1.0 mm in diameter (eight from the base plate or grapple fixture and one on clamp C03), and one feature on the base plate was slightly larger than 1.0 mm in diameter. Seventy three of the remaining features were located on various portion of the tray flanges or walls. Sixty one of these features were <0.5 mm in diameter and were not photodocumented. Eleven of the features that were photodocumented were between 0.5 and 1.0 mm in diameter and one feature ~1.0 mm in diameter. Three additional features of unknown size were concealed beneath the tray-stand clamping mechanism, but were included in the <0.5 mm category in the Feature Summary table below. All examined impact features were typical of craters formed in aluminum under hypervelocity laboratory conditions.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	9	61	59	129
>0.5 mm	1	12	9	22
TOTALS	10	73	68	151

The largest impact features identified on experiment-tray C01 were (1) an ~1.0 mm diameter impact on the lower, inner tray wall or flange and (2) an ~1.1 mm diameter feature on the aluminum base plate to which the grapple fixture was attached.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the grapple-tray was mounted on the spacecraft and identified only three features that could be damaged or destroyed by the placing of the grapple-tray within the experiment-tray stand. There was no experiment-tray cover for the grapple trays. One feature each was identified on clamps C04 and C08. Both were in location to warrant concern for bolts removal and a request was made to use an open-end wrench when removing the bolts near these features.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of experiment-tray C01 was conducted on March 19, 1990 in the vertical position utilizing M&D SIG System #2. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3. The coordinates for all features on all hardware associated with this tray were measured utilizing a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC030001.C01	RC030001.C01	45	6		0.5	Al	*1*
AC030001.C01	BC030001.C01	45	6		0.5	Al	*1*
CC030001.C01	DC030001.C01	45	6		0.5	Al	
LC040001.C01	RC040001.C01	46	55		0.5 x 0.4	Al	*1*
AC040001.C01	BC040001.C01	46	55		0.5 x 0.4	Al	*1*
CC040001.C01	DC040001.C01	46	55		0.5 x 0.4	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000006.C01	RE000006.C01	0	740	105	0.9	Al	*f*
LE000007.C01	RE000007.C01	440	989		0.6	Al	*1*
AE000007.C01	BE000007.C01	440	989		0.6	Al	
LE000008.C01	RE000008.C01	315	960		0.9	Al	
LE000015.C01	RE000015.C01	196	25	80	1.0	Al	*1,2,f*
AE000015.C01	BE000015.C01	196	25	80	1.0	Al	*1,2,f*
CE000015.C01	DE000015.C01	196	25	80	1.0	Al	*1,2,f*
EE000015.C01	FE000015.C01	196	25	80	1.0	Al	*1,2,f*
GE000015.C01	HE000015.C01	196	25	80	1.0	Al	*1,2,f*
IE000015.C01	JE000015.C01	196	25	80	1.0	Al	*1,2,f*
KE000015.C01	LE000015.C01	196	25	80	1.0	Al	*2,f*
LE000016.C01	RE000016.C01	95	47	135	1.0	Al	*2,10,f*
LE000017.C01	RE000017.C01	379	20	65	0.5	Al	*f*
LE000018.C01	RE000018.C01	458	15	55	0.6	Al	*f*
LE000019.C01	RE000019.C01	556	-3	35	0.8	Al	*f*
LE000020.C01	RE000020.C01	555	-10	2	0.8	Al	*f*
LE000021.C01	RE000021.C01	754	10	50	0.8	Al	*3,4,f*
LE000022.C01	RE000022.C01	852	11	55	0.7	Al	*5,f*
LE000023.C01	RE000023.C01	908	30	115	0.9	Al	*6,f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.C01	RE000001.C01	414	490		1.0	Al	
LE000002.C01	RE000002.C01	357	700		0.5	Al	
LE000003.C01	RE000003.C01	1053	640		0.7	Al	
LE000004.C01	RE000004.C01	1093	410		0.5	Al	
LE000005.C01	RE000005.C01	527	610		0.6 x 0.5	Al	*7,8*
LE000009.C01	RE000009.C01	390	808		0.7	Al	
LE000010.C01	RE000010.C01	981	810		1.1	Al	*1*
AE000010.C01	BE000010.C01	981	810		1.1	Al	
LE000011.C01	RE000011.C01	491	138		0.8	Al	
LE000012.C01	RE000012.C01	145	275		0.9	Al	
LE000013.C01	RE000013.C01	525	222		0.5	Al	
LE000014.C01	RE000014.C01	703	280		0.5	Al	*7,9*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Bad image due to computer hardware failure.
2 - Wrong coordinates (X = 95, Y = 47, Z = 135) entered with image files.
3 - Wrong coordinates (X = 852, Y = 11, Z = 55) entered with image file.
4 - Image taken at 30° to right of normal of crater.
5 - Image taken at 10° to right of normal of crater.
6 - Image taken at 15° to right of normal of crater.
7 - Impact located on grapple fixture.
8 - Spall zone ~1.2 mm in diameter.
9 - Spall zone ~1.3 mm in diameter.
10 - Wrong coordinates (X = 196, Y = 25, Z = 80) entered with image file.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-383C-4418/4
On-Orbit
Pre-Deintegration - KSC-390C-1069.01, KSC-390C-1069.02
Post Deintegration - KSC-390C-3385.09
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - C01C03, C01C04, C01C06, and C01C08

LDEF LOCATION: C02
EXPERIMENT IDENTIFICATION: A0187-2
EXPERIMENT TITLE: CHEMICAL AND ISOTOPIC MEASUREMENTS OF MICROMETEOROIDS BY SECONDARY ION MASS SPECTROMETRY
PRINCIPAL INVESTIGATOR:

E. ZINNER
WASHINGTON UNIVERSITY
CAMPUS BOX 1105
ST. LOUIS, MISSOURI 63130

M0006
SPACE ENVIRONMENT EFFECTS

W. WARD
WRDC/MLBT
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

A0015
FREE-FLYER BIOSTACK EXPERIMENT

G. REITZ
DFVLR
INSTITUT FUR FLUGMEDIZIN
ABTILUNG BIOPHYSIK
LINDER HOHE, 5000 KOLN 90
FEDERAL REPUBLIC OF GERMANY

SUMMARY OF OBSERVATIONS

One third of the 6"-deep (15.2 cm) chromic anodized aluminum experiment tray in Bay C02 contained the active experiment M0006. The other two-thirds of the experiment-tray was taken up by the passive experiments A0187-2 and A0015. M0006 exposed advanced electro-optical and radiation sensor components, along with selected terrestrial plant seeds, to the space environment to determine the long duration exposure effects on these materials. The experiment samples were contained in a sealed experiment exposure control canister (EECC). The EECC was pre-programmed to open two weeks after deployment of LDEF and close one week prior to the expected retrieval of LDEF, for a sample exposure of approximately one year. The sealed EECC was reopened at Kennedy Space Center in a separate facility, and within an argon atmosphere to prevent contamination of samples. The exposed materials included four mirrors (one beryllium, one SiC, and two fused silica), a Nd^+:glass laser rod, a fiber optics cable, a variety of polymeric and semi-conductor materials (including CdSe, p-GaAs, n-GaAs, and GaAs), lithium fluoride radiation dosimeters, and seeds (hybrid 3358 corn, sugar pumpkin, giant gray-striped sunflower, garden bean [Tennessee green pod and bush Romano #14], Henderson's bush Lima bean, and Alaska pea). The LiF radiation dosimeters and the seeds were housed in a 6061-T6 aluminum tube inside the EECC. The EECC sample holder and the outer cover were chromic anodized 6061-T6 aluminum.

For A0015, this 1/3 partial tray, together with the whole Earth-end corner tray G02, made up the Free-Flyer Biostack Experiment. The A0015 experimental package consisted of two whole or partial trays designed to exposed biological specimens to the cosmic ray particle (high atomic number [Z]/high energy) space environment to determine the importance, effectiveness, and hazards of the structured components of cosmic radiation to man and any biological specimen in space. The experiment exposed twenty detector units (eight in this partial tray) with different shielding against space. Each detector unit consisted of a special sandwich construction of visual nuclear track detectors and monolayers of biological objects. These sandwiches were housed within chromic anodized 2017 aluminum detector containers. The experiment base support hardware consisted of chromic anodized 2024 aluminum plates. Chemglaze Z-306 black paint was used on the experiment back side for thermal control.

Experiment A0187-2 occupied the center one-third of this tray, as well as 2/3 of Bay E03 and the whole experiment tray in Bay E08. Experiment A0187-2 consisted of an array of micrometeoroid capture cells to collect interplanetary dust particles for chemical and isotopic compositional analysis. This experiment contained 40 capture cells. Each capture cell was composed of four 38 x 42 mm, 0.5 mm thick germanium crystal wafers bonded with 1 mm thick strips of silicone RTV to an 86 x 94 mm, 3 mm thick 6061-T6 aluminum backplate, and covered with 2 micron thick metallized (200 Å Au/Pd exterior, 1000 Å Ta interior) Mylar foils spaced 0.2 mm above the germanium. These meteoroid capture cells were attached to a mounting plate constructed from sandwiched (2.5 cm spacing) 0.5 mm thick 6061-T6 aluminum. The experiment was mounted flush with the experiment-tray flanges.

Only one of the 40 Mylar foils from experiment A0187-2 was still intact upon retrieval of LDEF. (This compares to 11 out of 77 and 0 out of 120 for trays E03 and E08, respectively.) The broken foils were still attached to the capture cell frames in many places. The majority of the foil material had rolled up into coils, which looked like shards, and projected at all angles from the surface. Some of this material had come off during LDEF rotation operations and contaminated other surfaces. The front of the imaging microscope had to be wiped down with anti-static pads to avoid attracting the Mylar shards.

Morphologically, impacts into aluminum were typical of craters produced in aluminum during laboratory hypervelocity impact tests. The impacts into the germanium and optical materials were typical of crystalline material impacts. There were associated front surface spall zones with most impacts. Some impacts, which apparently occurred when the Mylar foils were still intact, had associated debris rings surrounding them. Because this experimental surface was designed to disrupt incoming hypervelocity particles, the number and size of impact features should not be comparable to those observed on other surfaces with equivalent positions on LDEF. Also, the uncovered germanium surfaces were contaminated with bits of the broken foils and particles of the metal coatings from the foils. This made it extremely difficult to count small features, and some contamination features which were not actual impacts may have been counted as small impacts.

On experiment-tray C02, the M&D SIG survey visually identified a total of 58 impact features on all associated experiment-tray surfaces. These surfaces included the tray flanges and walls, the experiment-tray clamps, and the experiment-tray clamp bolts. On the experiment surfaces, 45 impacts were located. Of these, 40 of the impacts were <0.5 mm in diameter (two were photodocumented as they were considered to be of interest, and three were on the optical samples contained in the EECC of experiment M0006), three were between 0.5 mm and 1.0 mm in diameter, one was between 1.0 mm and 1.5 mm in diameter, and one was between 1.5 mm and 2.0 mm in diameter. Of the seven impacts on the experiment-tray flanges and walls, four were <0.5 mm in diameter and were not photodocumented, and three were between 0.5 mm and 1.0 mm in diameter. On the experiment-tray clamps, all six of the impacts identified were <0.5 mm in diameter and were not photodocumented.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	6	4	40	50
>0.5 mm		3	5	8
TOTALS	6	7	45	58

The largest impact features identified on tray C02 were (1) an ~1.8 mm diameter crater located on the M0006 aluminum EECC outer cover, (2) an ~1.3 mm diameter crater in a germanium cell of experiment A0187-2 which created an ~0.4 x 0.5 mm hole through the germanium in the center of the crater, (3) an ~0.8 mm diameter crater in the experiment-tray flanges, and (3) an ~0.3 mm crater on an experiment-tray clamp. The largest impact in the mirror samples from the M0006 EECC was an ~0.3 mm diameter crater in the beryllium mirror.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 20, 1990 while the experiment-tray was mounted on the spacecraft. This inspection identified two features which might be destroyed by attachment of the experiment-tray cover and no features which would be destroyed by emplacement in the experiment-tray rotator. In an effort to protect these interesting features within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges. One feature was identified on clamp C05.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations or spallation features on the front or back of the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

The detailed examination and photodocumentation of experiment-tray C02 was conducted on March 14, 1990 in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #1. The bolts, clamps and shims associated with this tray were scanned with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale. Two members of the M&D SIG A-Team were invited to observe the opening of the EECC from M0006 on March 23, 1990. The Principal Investigator allowed the members to bring the mirror samples back to the Satellite Assembly and Encapsulation Facility (SAEF) II for examination with M&D SIG System #1. The other EECC samples, as well as the sample base plate, have not been examined for impact features. The EECC sample base plate was provided to the M&D SIG by the Principal Investigator for future examination.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	64	959	61	-17
Center	623	957	618	-20
Far Right	1182	955	1174	-22

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.C02	RE000001.C02	807	978		0.7	Al	*1*
LE000009.C02	RE000009.C02	1136	-25		0.6	Al	*1*
LE000010.C02	RE000010.C02	-3	194		0.8	Al	*1*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000002.C02	RE000002.C02	516	849		1.3, 0.4 x 0.5	Ge (1-D)	*2,3*
LE000003.C02	RE000003.C02	492	803		0.8, 1.8	Ge (5-B)	*2,4,d*
LE000004.C02	RE000004.C02	954	800		1.8	Al	*5*
LE010004.C02	RE010004.C02	954	800		ND	Al	*5,6,i,x*
LE000005.C02	RE000005.C02	684	640		0.5, 2.8	Ge (15-B)	*2,7,8,d*
LE000006.C02	RE000006.C02	1048	613		0.7	Al	*5*
LE000007.C02	RE000007.C02	454	34		0.5, 1.9	Ge (37-C)	*2,8,d*
LE000008.C02	RE000008.C02	789	25		ND	Ge (40-D)	*2,9,m*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

Ge (n-n) - Indicates impact into germanium capture cell with the Principal Investigator's identifying cell number.
ND - Not Determined

1 - Experiment number entered into image file is for the experiment closest to this impact into the experiment-tray flange.
2 - Impact into experiment A0187-2.
3 - Diameter after comma is diameter of hole in Ge in center of crater.
4 - Length after comma is length of spray pattern.
5 - Impact into experiment M0006 cover plate.
6 - Image of back side of crater in experiment M0006 cover plate; image taken using M&D SIG System #1.
7 - Wrong coordinates (X = 760, Y = 689) and wrong germanium cell number (12-C) input into image file.
8 - Diameter after comma is diameter of debris ring around crater.
9 - No identifiable crater in this feature; may not be impact related feature; long cracks and fracture of the Ge cell.

OTHER PHOTODOCUMENTATION:

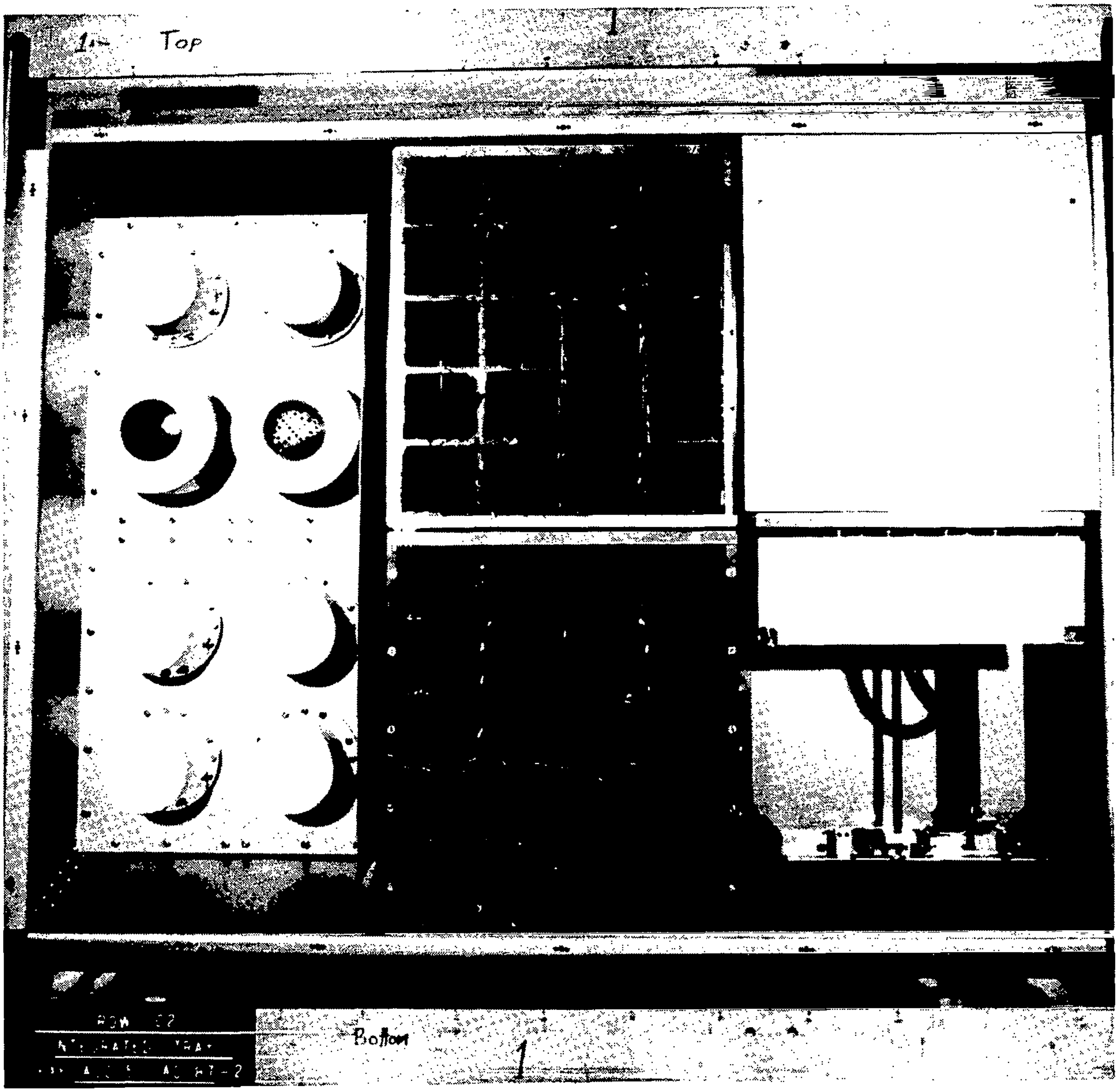
Pre-Flight - 108-KSC-384C-144/3
On-Orbit - S32-89-029
Pre-Deintegration - KSC-390C-1065.07, KSC-390C-1065.08, KSC-390C-1066.05
Post Deintegration - KSC-390C-1917.12
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - C02C03, C02C04, C02C05, and C02C08
Other - C02E02 - M0006 mirror
C02E03 - M0006 mirror
C02E04 - M0006 EECC aluminum sample base plate
C02E05 - M0006 mirror
C02E06 - M0006 mirror

ACCOMPANYING FIGURES:

Figure C02-1. This post-deintegration view shows the front of the entire C02 integrated experiment tray. The active canister is present on the right.



LDEF LOCATION:	**C03**
EXPERIMENT IDENTIFICATION:	**A0023**
EXPERIMENT TITLE:	**MULTIPLE-FOIL MICROABRASION PACKAGE**
PRINCIPAL INVESTIGATOR:	**J.A.M. McDONNELL** **UNIT FOR SPACE SCIENCES** **UNIVERSITY OF KENT** **CANTERBURY, UNITED KINGDOM CT28EF**
	A0034 **ATOMIC-OXYGEN-STIMULATED OUTGASSING** **R. SCOTT** **SOUTHERN UNIVERSITY** **BATON ROUGE, LOUISIANA**
	A0114 **INTERACTION OF ATOMIC OXYGEN WITH SOLID SURFACES AT ORBITAL ALTITUDES** **J. GREGORY** **UNIVERSITY OF ALABAMA** **HUNTSVILLE, ALABAMA**
	A0201 **INTERPLANETARY DUST EXPERIMENT** **G. WEINBURG** **INSTITUTE FOR SPACE SCIENCES & TECHNOLOGY** **GAINESVILLE, FLORIDA 32609**

SUMMARY OF OBSERVATIONS

Bay C03 contained a 3"-deep (7.6 cm), integrated, passive experiment tray that housed two meteoroid/debris-type experiments (A0023 and A0201) and two experiments (A0034 and A0114) designed to study the effects of atomic-oxygen on various materials.

The A0023 experiment was designed to measure the density (flux), size, velocity, radial distribution, and composition of micro-particles in low-Earth orbit. The detectors exposed rolled aluminum foils as thin as 1.5 μm that were bonded to etched aluminum grids to support the foils and provide a rugged structure. The experiment was located in one-third sections of four trays (C03, E06, C09, and D12) spaced at 90° intervals around the periphery of the spacecraft, as well as two-thirds of one 3"-deep (7.6 cm) space-facing tray (H11).

Experiment A0034 exposed selected thermal-control surfaces to the effects of atomic oxygen. The experiment occupied one-sixth sized areas of two 3"-deep (7.6 cm) trays (C03 and C09). A total of 25 samples were

exposed on each tray to the space environment by means of ~2" diameter holes cut in an aluminum cover plate.

The second atomic-oxygen experiment (A0114) exposed a variety of solid disk (*e.g.*, Si, C, etc.) or thin-film coatings (*e.g.*, Ag, Au, Pt, Ni, Al, C, Si, Ge, and Li) on substrate disk mounted in an aluminum panel. Each sample had 50% of the front surface masked by an aluminum cover plate, the shadowed area being used as a control surface for measurements. In addition, several activation metal samples were included to investigate the effects of solar radiation on such materials. Finally, a passive attitude sensor was incorporated into each unit to determine the orientation of the LDEF spacecraft with respect to the velocity vector. The total experiment package exposed two identical one-sixth tray-sized units; one each on the leading- (C09) and trailing edge (C03).

The A0201 experiment occupied one-third of Bay C03, as well as all of Bay B12 and portions of Bays C09, D06, G10, and H11. This experiment exposed metal-oxide-silicon (MOS), capacitor-type detectors to the low-Earth meteoroid/debris environment. The objective of the MOS detectors was to obtain mass and velocity information on the particles impinging upon their surfaces. Two varieties of detectors totaling ~1 m^2 of exposed surface area were flown on A0201; sixty percent of the detector surfaces possessed an oxide coating of 0.4 μm thick, while the remaining 40 percent had a 1.0 μm thick oxide coating. Each one-third tray typically contained 80 MOS detectors and one Sun sensor; the remainder of the A0201 experiment consisted of aluminum mounting rings on an aluminum plate.

Impact features residing in the various aluminum hardware associated with each of the four experiments on C03 were typical of hypervelocity impacts into aluminum produced under laboratory conditions. Penetrations through the aluminum foils of A0023 varied from circular to elongate in shape; several penetration resembled tears and may not have resulted from the penetration of a hypervelocity particle. One impact on A0023 into the wire grid deposited debris across the surface of the aluminum foil. No impacts were documented in test specimen from either A0034 or A0114. Impacts into the originally smooth MOS detectors exhibited somewhat complex morphologies. Generally, such impacts possessed a deep central pit; the diameter of this pit was utilized by the M&D SIG A-Team for the 0.5 mm threshold criteria. Surrounding the central pits were spallation zones possessing diameters on the order of 1.25 to 3 times that of the central pit. Fractures or cracks radiating from the central pit/spall zone were commonly found in association with the larger impacts into the amorphous metal-oxide-silicon material.

The M&D SIG survey identified a total of 83 features on the C03 experiment tray including the experiment-tray bolts, clamps, shims, and flanges. Only 13 features were photodocumented from the C03 tray, six each of which resided in the A0023 and A0201 experiments, and one feature from experiment A0034. No features were photodocumented from the bolts, clamps, and shims associated with this tray. One ~0.3 mm diameter feature was found on clamp C01 and one ~0.1 mm diameter feature was identified in the circular paint specimen on clamp C05. The distribution (*i.e.*, tray lips verse experimental surfaces) of the features below the photodocumentation threshold were not recorded in the logbook.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm				*
>0.3 mm				
<0.5 mm	2			78*
>0.5 mm		1	2	
TOTALS	2			83

* - The locations of the "Too Smalls" were not documented.

The largest impact features identified on tray C03 were (1) an ~0.7 mm diameter crater on an inner tray wall and (2) an ~0.7 mm diameter penetration through one of the aluminum foils of A0023.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 20, 1990 while the experiment-tray was mounted on the spacecraft; no features were identified during this survey.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick experiment-tray flanges. There were strong shadowing effects noticeable on the backside of this experiment tray.

DOCUMENTATION:

Examination and photodocumentation of tray C03 was conducted on March 2, 1990 in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #3. The bolts, clamps, and shims associated with this tray were scanned with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	68	959	66	-15
Center	627	959	624	-16
Far Right	1185	959	1183	-15

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000013.C03	RE000013.C03	5	399	40	0.7	Al	*f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.C03	RE000001.C03	127	784		0.7	Al	*1,2*
LE000002.C03	RE000002.C03	386	850		0.6 x 1.2	Al	*2*
LE000003.C03	RE000003.C03	317	637		0.2	Al	*2*
LE000004.C03	RE000004.C03	196	544		0.2	Al	*2,5,e*
LE000005.C03	RE000005.C03	479	806		0.7 x 1.0	Al	*3*
LE000006.C03	RE000006.C03	1144	886		0.2	MOS	*4*
LE000007.C03	RE000007.C03	1130	682		0.3	Al	*e*
LE000008.C03	RE000008.C03	966	647		0.3	MOS	*1,4*
LE000009.C03	RE000009.C03	291	403		0.5 x 0.7	Al	*1,d*
LE000010.C03	RE000010.C03	1027	262		0.3	MOS	*4,m*
LE000011.C03	RE000011.C03	891	129		0.2	MOS	*4*
LE000012.C03	RE000012.C03	1036	134		0.2	MOS	*4,6*
AE000012.C03	BE000012.C03	1036	134		0.2	MOS	*4,6*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

MOS - Metal-oxide-silicon

1 - Penetration through aluminum foil.
2 - Feature located on experiment A0023.
3 - Feature located on experiment A0034.
4 - Feature located on experiment A0201.
5 - Impact into aluminum support grid.
6 - Penetration through MOS detector and RTV into aluminum base plate.

OTHER PHOTODOCUMENTATION:

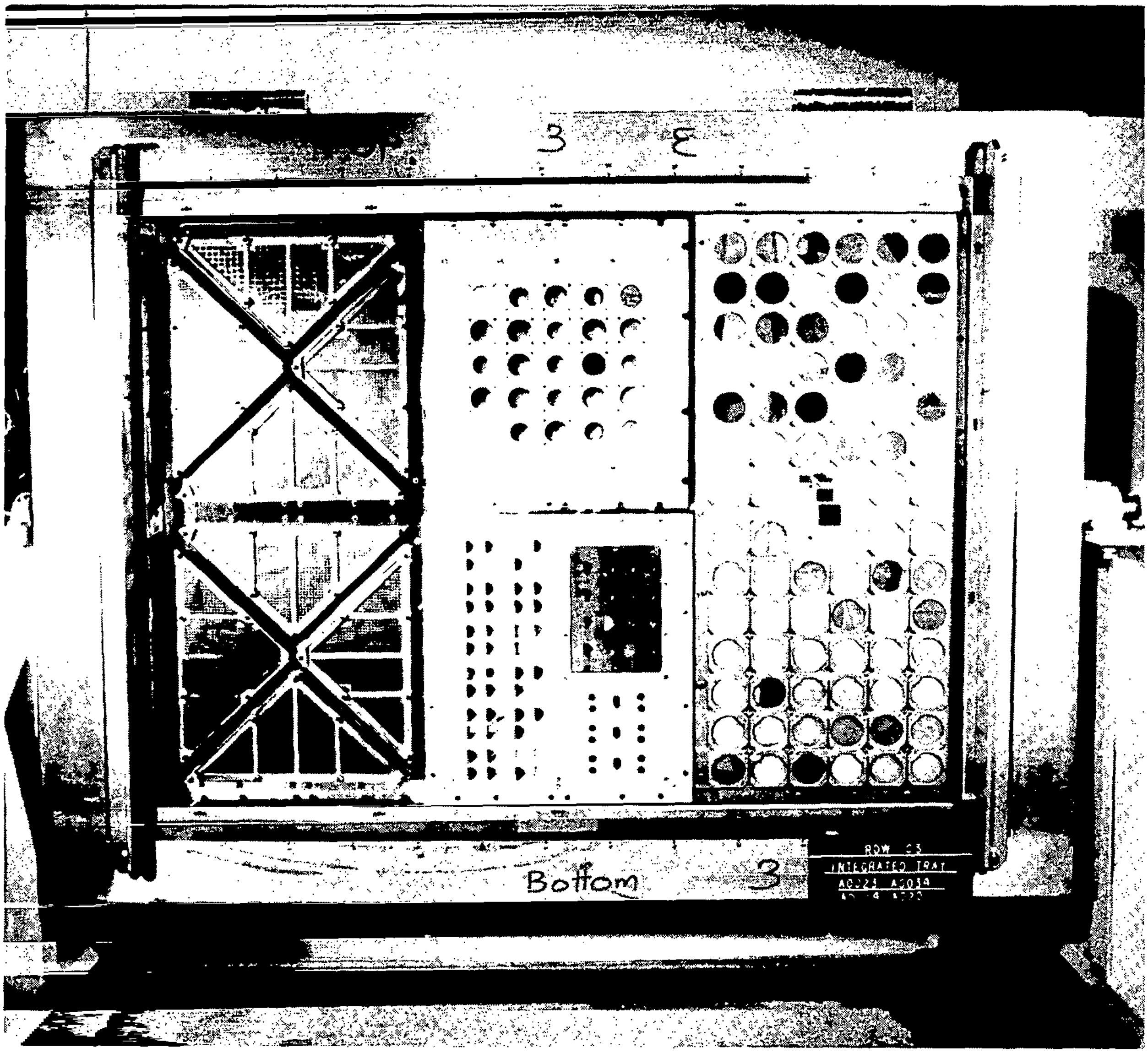
Pre-Flight - 84-07015, 108-KSC-384C-15/4, 108-KSC-384C-15/5, 108-KSC-384C-15/9
On-Orbit - S32-77-065
Pre-Deintegration - KSC-390C-1065.01, KSC-390C-1065.02, KSC-390C-883.12
Post Deintegration - KSC-390C-1546.04, KSC-390C-1558.02
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - C03C01, C03C04, C03C05, and C03C08

ACCOMPANYING FIGURES:

Figure C03-1. This post-deintegration view shows the front of the entire C03 integrated experiment tray.


3
Bottom 3
ROW C3
INTEGRATED TRAY

LDEF LOCATION: C04
EXPERIMENT IDENTIFICATION: S0001
EXPERIMENT TITLE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES
493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay C04 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays that were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

On experiment-tray C04, the M&D SIG survey visually identified a total of eight impact features on all associated experiment-tray surfaces. However, a survey for impact features <0.5 mm was not conducted. The associated experiment-tray surfaces included the tray flanges and walls, the experiment-tray clamps, and the experiment-tray clamp bolts. On the experiment surface, two impacts were located, both of which were between 0.5 mm and 1.0 mm in diameter. Five impacts were identified on the experiment-tray flanges; three of these were <0.5 mm in diameter (one of which was photodocumented as it was considered to be of interest), and two were between 0.5 mm and 1.0 mm in diameter. On the experiment-tray clamps, one impact was identified and it was <0.5 mm in diameter. All features were typical of craters produced in aluminum during laboratory hypervelocity impact tests.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	1			4@
>0.5 mm		2	2	4
TOTALS	1			8

@ - The survey for "Too Smalls" was not conducted.

The largest impact features identified on tray C04 were (1) an ~0.9 mm diameter crater located on the tray surface, (2) an ~1.0 mm diameter crater on the experiment-tray flange, and (3) an ~0.3 mm crater on an experiment-tray clamp.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 22, 1990 while the experiment-tray was mounted on the spacecraft. This inspection identified six features which might be destroyed by attachment of the experiment-tray cover and four features which would be destroyed by emplacement in the experiment-tray rotator. These latter impact features were estimated to be <0.5 mm in diameter. These features were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the more interesting feature within the experiment-tray cover area, the cover gasket was cut in one location to

prevent it from coming into contact with this feature and to provide a stand-off for the experiment tray cover and the tray flanges. One feature was identified on clamp C04.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.0625" (1.6 mm) thick experiment-tray flanges. However, there were some deep scars on the back of the flanges. The Principal Investigator believed the scars to be from clamps used during the pre-launch shake testing.

DOCUMENTATION:

The detailed examination and photodocumentation of experiment-tray C04 was conducted on March 1, 1990 in the horizontal position utilizing M&D SIG System #2. The bolts, clamps and shims associated with this tray were scanned with M&D SIG System #3. The coordinates for all features were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.C04	RE000001.C04	391	-35		0.6	Al	*1*
LE000004.C04	RE000004.C04	-14	740		1.0	Al	
LE000005.C04	RE000005.C04	-25	865		0.5	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.C04	RE000002.C04	638	47		0.5	Al	
LE000003.C04	RE000003.C04	1129	251		0.9	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Wrong coordinates (X = 393, Y = 35) input into image file.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-77-031
Pre-Deintegration - KSC-390C-1065.5, KSC-390C-1065.06, KSC-390C-832.05
Post Deintegration
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - C04C03, C04C04, C04C06, and C04C08

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION: C05
EXPERIMENT IDENTIFICATION: A0178
EXPERIMENT TITLE: A HIGH-RESOLUTION STUDY OF ULTRA-HEAVY COSMIC-RAY NUCLEI
PRINCIPAL INVESTIGATOR: D. O'SULLIVAN
DUBLIN INSTITUTE FOR ADVANCED STUDIES
DUBLIN, IRELAND

SUMMARY OF OBSERVATIONS

Bay C05 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46" long (~116.8 cm), 10" (25.4 cm) in diameter, 6063-T6 aluminum cylinders (1.9 mm thick) which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with an ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (space facing) of FEP teflon (~120 μm thick) backed with a thin layer of vapor-deposited silver/inconel (~200 to 300 Å thick), which in turn was backed by DC1200 primer and Chemglaze Z306 black conductive paint (~80 to 100 μm thick). The blankets were attached to a 40-5052 aluminum support frame by ~1" x 2" (~2.5 x 5.1 cm) strips of velcro.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of the resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted teflon material. Commonly, the teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. Many possessed several sharp, distinct rings, while other exhibited a more continuous halo phenomenon where the changes from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impact craters into aluminum.

The M&D SIG survey identified a total of 37 features on the C05 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the thermal insulation blanket. Of these, 28 were found on the thermal blanket, all but a few representing penetration through the blanket. Twenty features on the blanket were below the 0.3 mm diameter photodocumentation threshold and eight features were between 0.3 mm and 1.0 mm in diameter. Tray C05 was one of the first experiment trays examined by the M&D SIG A-Team and the presence of features of any size on the experiment-tray flanges were not recorded. Nine features were found on the various clamps associated with this tray, only one of which was >0.5 mm in diameter. One shim (C07) had ejecta spray on it from an impact into the longeron between Rows 6 and 7.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm				20*@
>0.3 mm			8	8
<0.5 mm	8			8
>0.5 mm	1			1
TOTALS	9			37

* - The locations of the "Too Smalls" were not documented.

@ - The survey for "Too Smalls" was not conducted.

The largest impact features identified on tray C05 were (1) an ~0.5 mm diameter penetration hole into the thermal blanket and (2) an ~0.6 x 0.5 mm oblique feature on clamp C03.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 22, 1990 while the experiment-tray was mounted on the spacecraft and identified no features on the tray flanges to be of concern during the tray removal process.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of experiment-tray C05 was conducted on March 22, 1990 in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #3. The bolts, clamps, and shims associated with this tray were scanned with M&D SIG System #3.

Bolt-Hole Registration - Not Determined

Fiducial Mark Locations - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC030001.C05	RC030001.C05	100	34		0.6 x 0.5	Al	*k,j*
LC080001.C05	RC080001.C05	37	34		0.3	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.C05	RE000001.C05	66	761		0.2	TB	
LE000002.C05	RE000002.C05	359	773		0.3	TB	
LE000003.C05	RE000003.C05	619	872		0.3	TB	*1*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000004.C05	RE000004.C05	75	685		0.4 x 0.3	TB	*2*
AE000004.C05	BE000004.C05	75	685		0.4 x 0.3	TB	
LE000005.C05	RE000005.C05	349	669		0.3	TB	
LE000006.C05	RE000006.C05	596	649		0.5	TB	
LE000007.C05	RE000007.C05	168	595		0.3	TB	
LE000008.C05	RE000008.C05	287	442		0.4	TB	
LE000009.C05	RE000009.C05	729	413		0.4	TB	
LE000010.C05	RE000010.C05	1018	389		0.4	TB	
LE000011.C05	RE000011.C05	1024	398		0.2	TB	
LE000012.C05	RE000012.C05	1105	358		0.5	TB	
LE000013.C05	RE000013.C05	1105	358		0.5	TB	*2,3*
LE000014.C05	RE000014.C05	1174	542		0.4	TB	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

TB - Thermal Blanket (teflon, silver-inconel, binder, and paint)

1 - Image taken at 45° to normal of crater.
2 - Lower magnification view of previous image.
3 - Image is of Feature #12; should not have had #13 assigned.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-256/4
On-Orbit - S32-75-003
Pre-Deintegration - KSC-390C-1035.10, KSC-390C-1035.11, KSC-390C-1035.07
Post Deintegration - KSC-390C-1467.02, KSC-390C-1471.01
M&D SIG Photos - S90-43465, S90-43466 - Left 1/3 of Thermal Blanket; 1 front- and 1 back view.
S90-43467, S90-43468 - Center 1/3 of Thermal Blanket; 1 front- and 1 back view.
S90-43469, S90-43470 - Right 1/3 of Thermal Blanket; 1 front- and 1 back view.
S90-43471 - Experiment tray following removal of the thermal blanket.

ARCHIVED MATERIALS:

Clamps - C05C03, C05C04, C05C07, and C05C08
Clamp Shims - C05H07
Thermal Blanket - (C05E00A) The U.S. third (minus the Materials SIG specimen) reside at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds (minus the Materials SIG grounding-strap specimen) is being archived at ESTEC in The Netherlands. This Thermal Blanket was processed by the M&D SIG A-Team before the decision was made to place any fiducial marks on the thermal-blanket surface.

LDEF LOCATION:	**C06**
TRAY IDENTIFICATION:	**A0178**
EXPERIMENT PURPOSE:	**A HIGH-RESOLUTION STUDY OF ULTRA-HEAVY COSMIC-RAY NUCLEI**
PRINCIPAL INVESTIGATOR:	**D. O'SULLIVAN DUBLIN INSTITUTE FOR ADVANCED STUDIES DUBLIN, IRELAND**

SUMMARY OF OBSERVATIONS

Bay C06 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46" long (~116.8 cm), 10" (25.4 cm) in diameter, 6063-T6 aluminum cylinders (1.9 mm thick) which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with an ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (space facing) of FEP teflon (~120 μm thick) backed with a thin layer of vapor-deposited silver/inconel (~200 to 300 Å thick), which in turn was backed by DC1200 primer and Chemglaze Z306 black conductive paint (~80 to 100 μm thick). The blankets were attached to a 40-5052 aluminum support frame by ~1" x 2" (~2.5 x 5.1 cm) strips of velcro.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of the resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted teflon material. Commonly, the teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. Many possessed several sharp, distinct rings, while other exhibited a more continuous halo phenomenon where the changes from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impact craters into aluminum.

The M&D SIG survey identified a total of 63 features on the C06 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of the 63 impacts found, seven were located on the tray-bolts and clamps and were not imaged due to the impact size being less than the threshold limit of > 0.5 mm. One impact was found on the aluminum tray-flanges that met the photodocumentation threshold limit and was imaged and five were imaged on tray-clamps (C04, C05, C06, and C07). Fourteen impacts were found on the thermal insulation blanket and were not imaged due to the threshold limit of penetrations being > 0.3 mm. Forty-two impacts were imaged on the thermal insulation blanket and ranged in diameter from 0.8 mm to 1.2 mm.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm				14@
>0.3 mm			40	40
<0.5 mm	7			7
>0.5 mm	1	1		2
TOTALS	8			63

@ - The survey for "Too Smalls" was not conducted.

The largest impact feature identified on experiment-tray C06 was an elliptical penetration ~1.2 mm x ~0.7 mm in diameter through the thermal blanket. An additional image LE000018.C06 was taken to show the large spray pattern from this elliptical penetration.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 20, 1990 while the experiment-tray was mounted on the spacecraft and the M&D SIG identified three features that might be damaged by the placement of the experiment-tray cover and two additional features that could be damaged or destroyed by the placement of the experiment tray within the experiment tray stand. The latter impact features were not examined or photodocumented, nor were they included in the numerical summary given above. No alterations to the tray-cover gasket were required.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations of the 0.125" (3.2 mm) thick experiment-tray flanges and no bulges or spalls on the back of the tray flanges. There were gouges on the flat end flanges like those seen on experiment-tray F02 but not as deep. These gouges were not related to high velocity impacts.

DOCUMENTATION:

On February 24, 1990 experiment-tray C06 was inspected in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #2. M&D SIG System #2 was also utilized to image one spray pattern on February 26, 1990. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a small metric scale.

Bolt-Hole Registration (mm)

	TOP X	TOP Y	BOTTOM X	BOTTOM Y
Far Left	59	946	55	-27
Center	617	949	614	-26
Far Right	1175	950	1173	-25

Fiducial Mark Locations - Not Determined

Impact Features Imaged on Experimental-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC040001.C06	RC040001.C06	9	38		0.3	Al	
LC040002.C06	RC040002.C06	33	58		0.4	Al	
LC050001.C06	RC050001.C06	16	36		0.4	Al	
LC060001.C06	RC060001.C06	76	26		0.7	Al	
LC070001.C06	RC070001.C06	91	30		0.3	Al	*1,2,x*

Impact Features Imaged on Experimental-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000043.C06	RE000043.C06	1029	-37		0.6	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.C06	RE000001.C06	254	857		0.4	TB	*3*
LE000002.C06	RE000002.C06	291	797		0.3	TB	*3,5*
AE000002.C06	BE000002.C06	291	797		0.3	TB	*3,4*
LE000003.C06	RE000003.C06	623	787		0.4 x 0.5	TB	*3*
LE000004.C06	RE000004.C06	678	839		0.2 x 0.3	TB	*3*
LE000005.C06	RE000005.C06	726	879		0.2 x 0.3	TB	*3*
LE000006.C06	RE000006.C06	934	788		0.4	TB	*3*
LE000007.C06	RE000007.C06	1164	848		0.5	TB	*3*
LE000008.C06	RE000008.C06	1177	779		0.4	TB	*3,6*
LE000009.C06	RE000009.C06	36	703		0.6	TB	
LE000010.C06	RE000010.C06	72	507		0.3	TB	
LE000011.C06	RE000011.C06	106	288		0.4	TB	
LE000012.C06	RE000012.C06	130	356		0.6	TB	
LE000013.C06	RE000013.C06	217	729		0.4	TB	*6*
LE000014.C06	RE000014.C06	195	620		0.2	TB	*7*
LE000015.C06	RE000015.C06	181	568		0.2	TB	*6*
LE000016.C06	RE000016.C06	231	543		0.3	TB	
LE000017.C06	RE000017.C06	306	221		0.5	TB	
LE000018.C06	RE000018.C06	425	614		0.7 x 1.2	TB	
LE000018.C06	RE000018.C06	425	614		ND	TB	
LE000019.C06	RE000019.C06	448	407		0.4 x 0.6	TB	
LE000020.C06	RE000020.C06	431	414		0.4	TB	
LE000021.C06	RE000021.C06	532	736		0.4	TB	
LE000022.C06	RE000022.C06	561	267		0.5	TB	
LE000023.C06	RE000023.C06	662	714		0.3	TB	*9*
LE000024.C06	RE000024.C06	683	567		0.5	TB	*9*
LE000025.C06	RE000025.C06	647	429		0.1	TB	*4,9,10*
AE000025.C06	BE000025.C06	924	645		ND	TB	*5,9,11*
LE000026.C06	RE000026.C06	887	375		0.4	TB	
LE000027.C06	RE000027.C06	787	340		0.5	TB	
LE000028.C06	RE000028.C06	1136	716		0.4	TB	
LE000029.C06	RE000029.C06	1180	705		0.4	TB	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000030.C06	RE000030.C06	1157	525		0.4	TB	
LE000031.C06	RE000031.C06	1124	218		0.3	TB	
LE000032.C06	RE000032.C06	1138	213		0.3	TB	
LE000033.C06	RE000033.C06	80	133		0.3 x 0.4	TB	
LE000034.C06	RE000034.C06	116	87		0.5	TB	
LE000035.C06	RE000035.C06	178	168		0.3	TB	*12*
LE000036.C06	RE000036.C06	712	27		0.6	TB	
LE000037.C06	RE000037.C06	874	179		0.7	TB	
LE000038.C06	RE000038.C06	892	89		0.4	TB	
LE000039.C06	RE000039.C06	927	106		0.4	TB	*13*
LE000040.C06	RE000040.C06	1110	156		0.5	TB	
LE000041.C06	RE000041.C06	1141	126		0.3	TB	
LE000042.C06	RE000042.C06	1090	31		0.4	TB	
LE010001.C06	RE010001.C06	75	685		ND	TB	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

TB - Thermal Blanket (teflon, silver-inconel, binder, and paint)
ND - Not Determined

1 - Spall zone diameter ~0.45 mm.
2 - Piece of paint in image.
3 - Angle of microscope at 30° counter-clockwise.
4 - Higher magnification view of penetration.
5 - Lower magnification view to show extent of shock zone.
6 - Large halo around penetration.
7 - Odd (bow-tie) shaped halo around penetration.
8 - Spray pattern underneath thermal blanket from feature LE000018.C06 taken on System #1. Image store on system #2
9 - Penetration measured at bottom of hole.
10 - Oblique spallation pattern.
11 - Eliptical shock wave pattern.
12 - Cracks around rings.
13 - Asymetric rings.
14 - Spray pattern from unknown blanket penetration.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-332/8
On-Orbit - S32-85-097
Pre-deintegration - KSC-390C-1033.01, KSC-390C-1033.02, KSC-390C-1033.11
Post Deintegration
M&D SIG Photos - S90-43472 - Left 1/3 of Thermal Blanket; back view.
S90-43473, S90-43474 - Middle 1/3 of Thermal Blanket;front and back views.
S90-43475, S90-43476 - Right 1/3 of Thermal Blanket; front and back views.
S90-43477, S90-43478 - Tray C06 with Thermal Blanket removed.

ARCHIVED MATERIALS:

Clamps - C06C04, C06C06, C06C07, and C06C08

Thermal Blanket - (C06E00A) - The U.S. third (minus the Materials SIG specimen) reside at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds (minus the Materials SIG grounding-strap specimen) is being archived at ESTEC in The Netherlands. Each blanket third was marked with two small crosses (see Fiducial Mark table above) for indexing and reconstruction purposes.

LDEF LOCATION: C07
TRAY IDENTIFICATION: S0001
EXPERIMENT PURPOSE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: DON H. HUMES,
493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay C07 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays that were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 334 features on the C07 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of the 334 impacts found, 294 were <0.5 mm and were not imaged, the remaining 42 that were imaged ranged in diameter from 0.3 mm to 1.6 mm. Of the 42 imaged impacts, six were located on the tray flanges and ranged in size from 0.5 mm to 1.3 mm in diameter, two were located on tray-clamps C03 and C05 and were ~0.6 mm and ~0.7 mm in diameter respectively, and the remaining 34 impacts were located on the aluminum tray surface and ranged in size from 0.5 mm to 1.6 mm in diameter. All features were typical of craters produced in aluminum during laboratory hypervelocity impact tests.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm				295*
>0.5 mm	2	6	31	39
TOTALS	2			334

* - The locations of the "Too Smalls" were not documented.

The largest impact features identified on experiment-tray C07 were (1) a circular impact ~1.3 mm in diameter located on the bottom tray flange and (2) a circular impact ~1.6 mm in diameter located on the tray surface.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 22, 1990 while the experiment-tray was mounted on the spacecraft and the M&D SIG identified eight features that might be damaged by the placement of the experiment-tray cover and one additional feature that could be damaged or destroyed by the placement of the experiment tray within the experiment tray stand. The latter impact feature was not examined or photodocumented, nor was it included in the numerical summary given above. In an effort to protect the more interesting feature within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations of the 0.0625" (1.6 mm) thick experiment-tray flanges and no bulges or spalls on the back of the tray flanges.

DOCUMENTATION:

On March 20, 1990 the S0001 tray was inspected in the horizontal position utilizing M&D SIG System #3. The detailed inspection of the experiment-tray and the inspection of the clamps and bolts was also performed on March 20, 1990, using M&D SIG System #3; the coordinates for all features residing on this tray were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experimental-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC030001.C07	RC030001.C07	110	0	-1	0.7	Al	
LC050002.C07	RC050002.C07	85	35		0.6	Al	

Impact Features Imaged on Experimental-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.C07	RE000001.C07	340	-20		0.6	Al	
LE000018.C07	RE000018.C07	1277	44		0.5	Al	*w*
LE000037.C07	RE000037.C07	575	950		0.5	Al	*v*
LE000038.C07	RE000038.C07	65	950		0.9	Al	*v*
LE000039.C07	RE000039.C07	0	613	68	0.7	Al	*f,v*
LE000040.C07	RE000040.C07	0	442	50	1.3	Al	*f,v*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.C07	RE000002.C07	303	34		0.5	Al	
LE000003.C07	RE000003.C07	206	232		0.7	Al	
LE000004.C07	RE000004.C07	291	258		0.6	Al	
LE000005.C07	RE000005.C07	475	198		0.7	Al	
LE000006.C07	RE000006.C07	525	213		0.9	Al	
LE000007.C07	RE000007.C07	72	360		1.1	Al	
LE000008.C07	RE000008.C07	150	346		0.7	Al	
LE000009.C07	RE000009.C07	248	333		0.9	Al	
LE000010.C07	RE000010.C07	249	330		0.7	Al	
LE000011.C07	RE000011.C07	288	360		0.6	Al	
LE000012.C07	RE000012.C07	329	875		0.6	Al	*x*
LE000013.C07	RE000013.C07	155	850		0.7	Al	*x*
LE000014.C07	RE000014.C07	139	820		0.5	Al	*x*
LE000015.C07	RE000015.C07	190	777		0.3	Al	*x*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000016.C07	RE000016.C07	1140	337		0.5	Al	*w*
LE000017.C07	RE000017.C07	1225	68		1.1	Al	*w*
LE000019.C07	RE000019.C07	200	707		0.5	Al	*z*
LE000020.C07	RE000020.C07	280	728		0.6	Al	*z*
LE000021.C07	RE000021.C07	359	720		0.6 x 0.8	Al	*z*
LE000022.C07	RE000022.C07	511	665		0.6	Al	*z*
LE000023.C07	RE000023.C07	530	605		0.5	Al	*z*
LE000024.C07	RE000024.C07	515	555		0.6	Al	*z*
LE000025.C07	RE000025.C07	280	530		0.7	Al	*1,y*
LE000026.C07	RE000026.C07	280	530		0.7	Al	*1,z*
LE000027.C07	RE000027.C07	727	715		0.5	Al	*z*
LE000028.C07	RE000028.C07	735	751		0.9	Al	*d,z*
LE000029.C07	RE000029.C07	709	625		0.7	Al	*z*
LE000030.C07	RE000030.C07	648	610		1.6	Al	*z*
LE000031.C07	RE000031.C07	830	478		0.9	Al	*z*
LE000032.C07	RE000032.C07	928	604		0.5	Al	*2,z*
LE000033.C07	RE000033.C07	1250	685		0.5	Al	*2,z*
LE000034.C07	RE000034.C07	1080	759		1.3	Al	*z*
LE000035.C07	RE000035.C07	1160	511		0.8	Al	*z*
LE000036.C07	RE000036.C07	1228	462		0.9	Al	*z*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - This image is a duplicate of image #11.
2 - Goosenecks were used for illumination instead of the ring light.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-85-093
Pre-deintegration - KSC-390C-1032.05, KSC-390C-1032.08, KSC-390C-1032.09
Post Deintegration - KSC-390C-2161.07
M&D SIG Photos - None

ARCHIVED MATERIALS

Clamps - C07C03, C07C04, C07C05, and C07C08

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION: C08
EXPERIMENT IDENTIFICATION: A0178
EXPERIMENT TITLE: A HIGH-RESOLUTION STUDY OF ULTRA-HEAVY COSMIC-RAY NUCLEI

PRINCIPAL INVESTIGATOR: D. O'SULLIVAN
DUBLIN INSTITUTE FOR ADVANCED STUDIES
DUBLIN, IRELAND

SUMMARY OF OBSERVATIONS

Bay C08 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46" long (~116.8 cm), 10" (25.4 cm) in diameter, 6063-T6 aluminum cylinders (1.9 mm thick) which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with an ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (space facing) of FEP teflon (~120 μm thick) backed with a thin layer of vapor-deposited silver/inconel (~200 to 300 Å thick), which in turn was backed by DC1200 primer and Chemglaze Z306 black conductive paint (~80 to 100 μm thick). The blankets were attached to a 40-5052 aluminum support frame by ~1" x 2" (~2.5 x 5.1 cm) strips of velcro.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of the resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted teflon material. Commonly, the teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. Many possessed several sharp, distinct rings, while other exhibited a more continuous halo phenomenon where the changes from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impact craters into aluminum.

The M&D SIG survey identified a total of 371 features on the C08 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the thermal insulation blanket. Two hundred and fifty six features from the blanket were below the 0.3 mm diameter photodocumentation threshold (two "Too Smalls" were imaged because they were considered of interest), 90 features were between 0.3 mm and 1.0 mm in diameter, and 3 features were photodocumented that were between 1.0 mm and 1.5 mm in diameter. Six features were found on the tray flanges, three of which were between 0.5 mm and 1.0 mm in diameter, and three of which were between 1.0 mm and 1.5 mm in diameter. The remaining five features were located while scanning the associated bolts, clamps and shims for experiment-tray C08. Fourteen features on the clamps (C01-C08) were <0.5 mm in diameter, five were between 0.5 mm and 1.0 mm in diameter and located on clamps (C02, C03, C04, and C06).

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm				256*
>0.3 mm			40	40
<0.5 mm	14			14*
>0.5 mm	3	6	52	61
TOTALS	17			371

* - The locations of the "Too Smalls" were not documented.

The largest impact features documented on tray C08 were (1) an ~1.5 mm diameter crater located on the experiment-tray flange and (2) an ~1.3 mm in diameter penetration hole found in the thermal blanket was. A large ejecta spray pattern was documented on the aluminum frame beneath the blanket, which was caused by a particle penetrating the blanket. We rarely located such well-defined ejecta patterns on the A0178 trays beneath the blankets.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 22, 1990 while the experiment-tray was mounted on the spacecraft and identified ten features that might be damaged by the placement of the experiment-tray cover and four additional features that could be damaged or destroyed by the placing of the experiment-tray within the experiment-tray stand. The latter impact features were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in three locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of experiment-tray C08 was conducted on March 21, 1990 in the vertical position utilizing M&D SIG System and Coordinate Registration Systems #1. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a small metric scale.

Bolt-Hole Registration - Not Determined

Fiducial Mark Locations - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC020001.C08	RC020001.C08	35	17		0.5	Al	
LC020002.C08	RC020002.C08	86	20		0.4	Al	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC030001.C08	RC030001.C08	37	12		0.5	Al	
LC040001.C08	RC040001.C08	4	37		0.4	Al	
LC060001.C08	RC060001.C08	57	1		0.5	Al	

Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000019.C08	RE000019.C08	1250	746		1.5	Al	
LE000020.C08	RE000020.C08	950	930		1.2	Al	
LE000021.C08	RE000021.C08	785	962		1.2	Al	
LE000022.C08	RE000022.C08	500	959		0.6	Al	
LE000048.C08	RE000048.C08	1260	441		0.9	Al	
LE000071.C08	RE000071.C08	-14	170		0.7	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.C08	RE000001.C08	24	902		0.3	TB	
LE000002.C08	RE000002.C08	43	803		0.5	TB	
LE000003.C08	RE000003.C08	175	775		0.3	TB	
LE000004.C08	RE000004.C08	1154	930		0.3	TB	
LE000005.C08	RE000005.C08	337	615		0.4	TB	
LE000006.C08	RE000006.C08	331	608		1.2	TB	
LE000007.C08	RE000007.C08	406	870		0.4	TB	
LE000008.C08	RE000008.C08	375	825		0.4	TB	
LE000009.C08	RE000009.C08	358	704		0.2	TB	*1*
LE000010.C08	RE000010.C08	479	811		1.3	TB	
LE000011.C08	RE000011.C08	864	887		0.5	TB	
LE000012.C08	RE000012.C08	959	827		0.5	TB	
LE000013.C08	RE000013.C08	976	799		0.5	TB	
LE000014.C08	RE000014.C08	1132	806		0.7	TB	
LE000015.C08	RE000015.C08	1210	803		0.6	TB	
LE000016.C08	RE000016.C08	1131	663		0.5	TB	
LE000017.C08	RE000017.C08	1130	488		0.5	TB	
LE000018.C08	RE000018.C08	1212	533		0.4	TB	
LE000023.C08	RE000023.C08	63	528		0.6	TB	
LE000024.C08	RE000024.C08	51	409		0.5	TB	
LE000025.C08	RE000025.C08	175	437		0.5	TB	
LE000026.C08	RE000026.C08	235	566		0.5	TB	
LE000027.C08	RE000027.C08	289	426		0.5	TB	
LE000028.C08	RE000028.C08	303	447		0.4	TB	
LE000029.C08	RE000029.C08	315	456		0.5	TB	
LE000030.C08	RE000030.C08	308	587		0.9	TB	
LE000031.C08	RE000031.C08	311	595		0.5	TB	
LE000032.C08	RE000032.C08	332	604		0.8	TB	
LE000033.C08	RE000033.C08	338	612		0.5	TB	
LE000034.C08	RE000034.C08	387	501		0.5	TB	
LE000035.C08	RE000035.C08	472	424		0.5	TB	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000036.C08	RE000036.C08	713	482		0.5	TB	
LE000037.C08	RE000037.C08	751	457		0.4	TB	2
LE000038.C08	RE000038.C08	731	412		0.5	TB	
LE000039.C08	RE000039.C08	798	450		0.4	TB	
LE000040.C08	RE000040.C08	899	550		0.6	TB	
LE000041.C08	RE000041.C08	964	402		0.3	TB	
LE000042.C08	RE000042.C08	955	390		0.4	TB	
LE000043.C08	RE000043.C08	975	430		0.2	TB	3
LE000044.C08	RE000044.C08	989	503		0.3	TB	
LE000045.C08	RE000045.C08	1040	389		0.3	TB	
LE000046.C08	RE000046.C08	1131	488		0.5	TB	
LE000047.C08	RE000047.C08	1214	534		0.4	TB	
LE000049.C08	RE000049.C08	1049	288		0.5	TB	
LE000050.C08	RE000050.C08	969	251		0.4	TB	
LE000051.C08	RE000051.C08	965	313		0.5	TB	
LE000052.C08	RE000052.C08	921	417		0.3	TB	
LE000053.C08	RE000053.C08	898	235		0.2 x 0.4	TB	
LE000054.C08	RE000054.C08	804	195		0.2 x 0.5	TB	
LE000055.C08	RE000055.C08	777	234		0.3	TB	
LE000056.C08	RE000056.C08	802	229		0.4	TB	
LE000057.C08	RE000057.C08	720	228		0.4	TB	
LE000058.C08	RE000058.C08	681	315		0.4	TB	
LE000059.C08	RE000059.C08	640	295		0.3	TB	
LE000060.C08	RE000060.C08	603	259		0.3	TB	
LE000061.C08	RE000061.C08	571	261		0.4	TB	
LE000062.C08	RE000062.C08	560	233		0.6	TB	
LE000063.C08	RE000063.C08	521	310		0.5	TB	
LE000064.C08	RE000064.C08	458	339		0.7	TB	
LE000065.C08	RE000065.C08	263	396		0.5	TB	
LE000066.C08	RE000066.C08	244	295		0.3	TB	
LE000067.C08	RE000067.C08	226	307		0.5	TB	
LE000068.C08	RE000068.C08	204	396		0.3	TB	
LE000069.C08	RE000069.C08	193	292		0.4 x 0.8	TB	
LE000070.C08	RE000070.C08	77	284		0.3	TB	
LE000072.C08	RE000072.C08	5	33		0.4	TB	4
LE000073.C08	RE000073.C08	13	169		0.5	TB	4
LE000074.C08	RE000074.C08	76	98		0.3	TB	
LE000075.C08	RE000075.C08	169	4		0.5	TB	7
LE000076.C08	RE000076.C08	196	8		0.6	TB	5
LE000077.C08	RE000077.C08	187	152		0.6	TB	
LE000078.C08	RE000078.C08	327	192		0.4	TB	
LE000079.C08	RE000079.C08	334	144		0.7	TB	
LE000080.C08	RE000080.C08	357	164		0.5	TB	
LE000081.C08	RE000081.C08	375	97		0.4	TB	
LE000082.C08	RE000082.C08	409	190		0.9	TB	
LE000083.C08	RE000083.C08	465	51		0.5	TB	
LE000084.C08	RE000084.C08	513	28		0.4	TB	
LE000085.C08	RE000085.C08	501	80		0.3	TB	
LE000086.C08	RE000086.C08	486	198		0.7	TB	
LE000087.C08	RE000087.C08	653	28		0.5	TB	
LE000088.C08	RE000088.C08	752	50		0.8	TB	
LE000089.C08	RE000089.C08	729	160		0.4	TB	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000090.C08	RE000090.C08	792	138		0.6	TB	
LE000091.C08	RE000091.C08	828	104		0.5	TB	
LE000092.C08	RE000092.C08	889	185		0.5	TB	*1*
LE000093.C08	RE000093.C08	890	10		0.6	TB	
LE000094.C08	RE000094.C08	1026	42		1.3	TB	
LE000095.C08	RE000095.C08	1042	112		0.5	TB	
LE000096.C08	RE000096.C08	1105	174		0.4	TB	
LE000097.C08	RE000097.C08	1125	116		0.6	TB	
LE000098.C08	RE000098.C08	1210	49		0.6	TB	
LE000099.C08	RE000099.C08	315	595		ND	Al	*6*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

TB - Thermal Blanket (teflon, silver-inconel, binder, and paint)
ND - Not Determined

1 - Impact feature doublet, second diameter D=0.2 mm.
2 - No rings around impact feature.
3 - Interesting pattern around impact feature.
4 - Oblique impact.
5 - Impact feature located 30° from normal.
6 - Not a primary impact feature, this is an ejecta spray pattern the velcro frame beneath the blanket.
7 - Image taken at a 60° angle to the crater.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-348C-372/3
On-Orbit - S32-76-08
Pre-Deintegration - KSC-390C-1031.03, KSC-390C-1031.04, KSC-390C-1031.10
Post Deintegration - KSC-390C-1543.09, KSC-390C-1544.06
M&D SIG Photos None

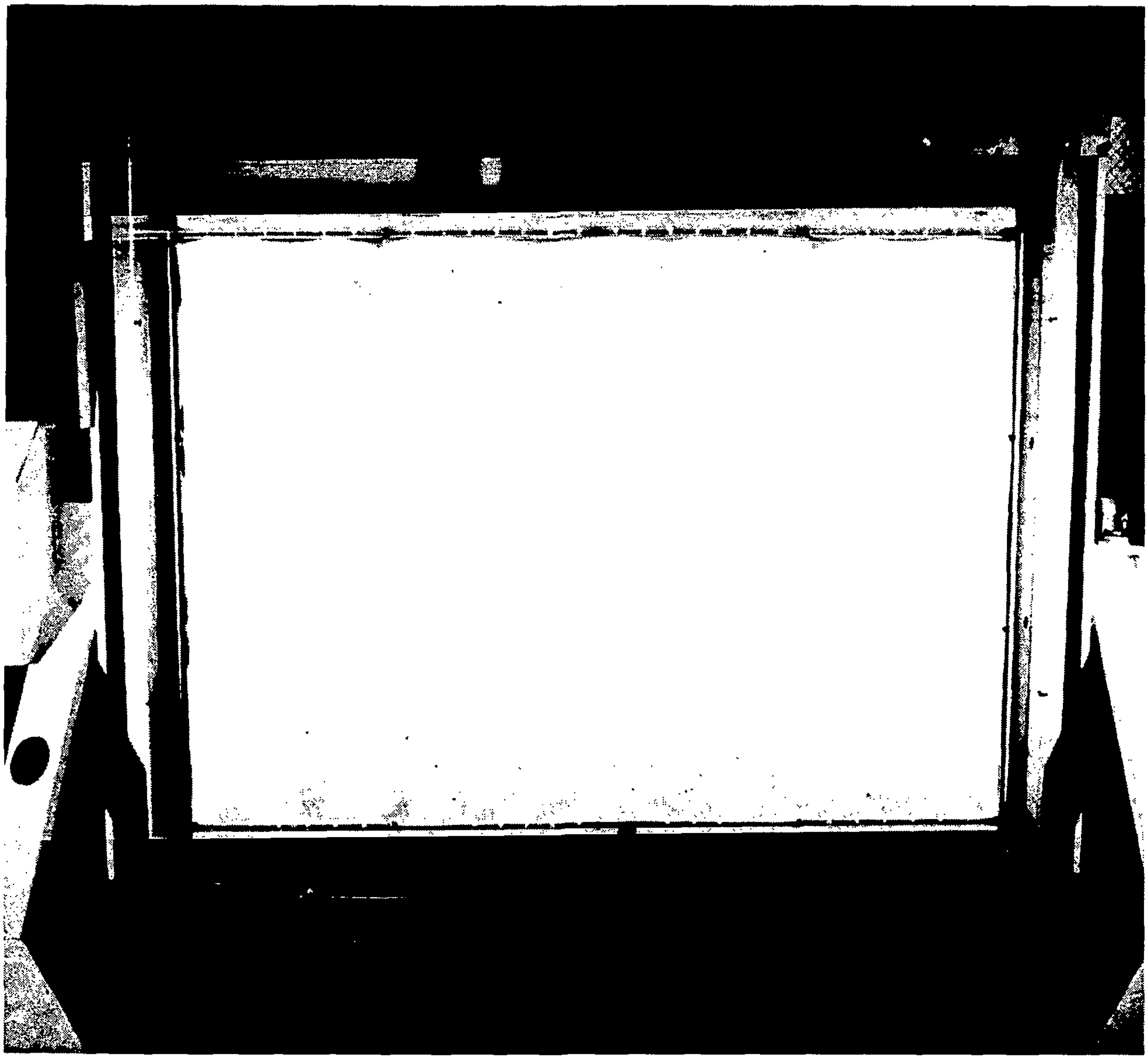
ARCHIVED MATERIALS:

Clamps - C08C02, C08C03, C08C04 and C08C06
Clamp Bolts - C08S01A and C08S03B
Thermal Blanket - (C08E00A) The U.S. third (minus the Materials SIG specimen) resides at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds (minus the Materials SIG grounding-strap specimen) is being archived at ESTEC in the Netherlands. Each blanket third was marked with two small crosses (see Fiducial Mark table above) for indexing and reconstruction purposes.

ACCOMPANYING FIGURES:

Figure C08-1. This post-deintegration view shows the front of the entire C08 experiment thermal blanket. Oxygen erosion has given this blanket a frosted appearance. The large impact (#94, with a streak) on the lower right is shown in Figure C08.

Figure C08-2. This view shows several impact penetrations on C08, most with rings and delamination areas. A large streak of impact-related origin accompanies feature #94. View measures approximately 21 cm across.



LDEF LOCATION:	**C09**
EXPERIMENT IDENTIFICATION:	**A0023**
EXPERIMENT TITLE:	**MULTIPLE-FOIL MICROABRASION PACKAGE**
PRINCIPAL INVESTIGATOR:	**J.A.M. McDONNELL** **UNIT FOR SPACE SCIENCES** **UNIVERSITY OF KENT** **CANTERBURY, UNITED KINGDOM CT28EF**
	A0034 **ATOMIC-OXYGEN-STIMULATED OUTGASSING** **R. SCOTT** **SOUTHERN UNIVERSITY** **BATON ROUGE, LOUISIANA**
	A0114 **INTERACTION OF ATOMIC OXYGEN WITH SOLID SURFACES AT ORBITAL ALTITUDES** **J. GREGORY** **UNIVERSITY OF ALABAMA** **HUNTSVILLE, ALABAMA**
	A0201 **INTERPLANETARY DUST EXPERIMENT** **G. WEINBURG** **INSTITUTE FOR SPACE SCIENCES & TECHNOLOGY** **GAINESVILLE, FLORIDA 32609**

SUMMARY OF OBSERVATIONS

Bay C09 contained a 3"-deep (7.6 cm), integrated, passive experiment tray that housed two meteoroid/debris-type experiments (A0023 and A0201) and two experiments (A0034 and A0114) designed to study the effects of atomic-oxygen on various materials.

The A0023 experiment was designed to measure the density (flux), size, velocity, radial distribution, and composition of micro-particles in low-Earth orbit. The detectors exposed rolled aluminum foils as thin as 1.5 μm that were bonded to etched aluminum grids to support the foils and provide a rugged structure. The experiment was located in one-third sections of four trays (C03, C09, E06, and D12) spaced at 90° intervals around the periphery of the spacecraft, as well as two-thirds of one 3" deep space-facing tray (H11).

Experiment A0034 exposed selected thermal-control surfaces to the effects of atomic oxygen. The experiment occupied one-sixth sized areas of two 3"-deep (7.6 cm) trays (C03 and C09). A total of 25 samples were exposed on each tray to the space environment by means of ~2" diameter holes cut in an aluminum cover plate.

The second atomic-oxygen experiment (A0114) exposed a variety of solid disk (*e.g.*, Si, C, etc.) or thin-film coatings (*e.g.*, Ag, Au, Pt, Ni, Al, C, Si, Ge, and Li) on substrate disk mounted in an aluminum panel. Each sample had 50% of the front surface masked by an aluminum cover plate, the shadowed area being used as a control surface for measurements. In addition, several activation metal samples were included to investigate the effects of solar radiation on such materials. Finally, a passive attitude sensor was incorporated into each unit to determine the orientation of the LDEF spacecraft with respect to the velocity vector. The total experiment package exposed two identical one-sixth tray-sized units; one each on the leading- (C09) and trailing edge (C03).

The A0201 experiment occupied one-third of Bay C09, as well as all of Bay B12 and portions of Bays C09, D06, G10, and H11. This experiment exposed metal-oxide-silicon (MOS), capacitor-type detectors to the low-Earth meteoroid/debris environment. The objective of the MOS detectors was to obtain mass and velocity information on the particles impinging upon their surfaces. Two varieties of detectors totaling ~1 m^2 of exposed surface area were flown on A0201; sixty percent of the detector surfaces possessed an oxide coating of 0.4 μm thick, while the remaining 40 percent had a 1.0 μm thick oxide coating. Each one-third tray typically contained 80 MOS detectors and one Sun sensor; the remainder of the A0201 experiment consisted of aluminum mounting rings on an aluminum plate.

Impact features residing in the various aluminum hardware associated with each of the four experiments on C09 were typical of hypervelocity impacts into aluminum produced under laboratory conditions. Penetrations through the aluminum foils of A0023 varied from circular to elongate in shape; several penetration resembled tears and may not have resulted from the penetration of a hypervelocity particle. One impact on A0023 into the wire grid deposited debris across the surface of the aluminum foil. No impacts were documented in test specimen from either A0034 or A0114. Impacts into the originally smooth MOS detectors exhibited somewhat complex morphologies. Generally, such impacts possessed a deep central pit; the diameter of this pit was utilized by the M&D SIG A-Team for the 0.5 mm threshold criteria. Surrounding the central pits were spallation zones possessing diameters on the order of 1.25 to 3 times that of the central pit. Fractures or cracks radiating from the central pit/spall zone were commonly found in association with the larger impacts into the amorphous metal-oxide-silicon material.

The M&D SIG survey identified a total of 508 features on the C09 experiment tray including the experiment-tray bolts, clamps, shims, and flanges. Information on 35 of these features was not obtained due to time-constraints placed on the M&D SIG A-Team by outside sources; the Feature Summary table below does not include those 35 features. Of the remaining 473 features, 347 resided on various experimental hardware and 126 were identified from the experiment-tray flanges and the various clamps, bolts, and shims associated with tray C09. Six penetrations on A0023 were >0.3 mm in diameter and were photodocumented; three additional feature that were located on the aluminum grid structure were also photodocumented. Only three features were found to be <0.3 mm in diameter during the actual photodocumentation of C09; some of the <0.5 mm features in the Feature Summary table below represent penetrations in the A0023 aluminum foil. Fifty three features were <0.5 mm in diameter on either the MOS detectors or Si specimen, nine were between 0.5 and 1.0 mm in diameter, and three were between 1.0 and 1.5 mm in diameter. One of the later features represented a penetration through one of the MOS detectors. Twenty seven feature were found to be <0.5 mm in diameter on various pieces of aluminum from the four experiments on tray C09. Twenty one features were between 0.5 and 1.0 mm in diameter and two features were between 1.0 and 1.5 mm in diameter; all of the features >0.5 mm in diameter were photodocumented. A total of 75 features were found on the various portions of the tray flanges, 69 of which were <0.5 mm in diameter. A total of 51 features were identified on the various clamps, three of which were >0.5 mm in diameter. Several features on the experimental surfaces and the clamps were photodocumented that were below the threshold diameter, but exhibited a characteristic

that warranted photodocumentation. One impact each was found on shim C03 and bolts C06A, C07B and C07C.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm				
>0.3 mm			6	6
<0.5 mm	48	69	303	420
>0.5 mm	3	6	35	44
TOTALS	51	75	344	473

The largest impact features identified on experiment-tray C09 were (1) an ~1.5 mm diameter feature within one of the MOS detectors, (2) an ~1.2 mm diameter feature in the aluminum plate of A0201, and (3) ~0.9 x 1.6 mm penetration feature in the aluminum foils collectors of A0023.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft and found five features that might be damaged by the emplacement of the experiment-tray cover; no features were identified within the tray-stand clamp area. Three features were found on bolts and special handling request were submitted to the Ground Operation personnel to be careful and to use an open-end wrench when loosening these bolts. In an effort to protect the most interesting feature within the experiment-tray cover area, the cover gasket was cut in one location to prevent it from coming into contact with the feature and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick experiment-tray flanges. There were outgassing patterns behind the various bolt holes in the tray flanges, as well as a wavy depositional feature around the rivets toward the back side of the tray surface.

DOCUMENTATION:

Examination and photodocumentation of experiment-tray C09 was conducted on March 2, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #2. The bolts, clamps, and shims associated with this tray were scanned with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	74	960	67	-15
Center	632	960	626	-16
Far Right	1191	960	1184	-16

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC010001.C09	RC010001.C09	4	13		0.3	Al	
LC010002.C09	RC010002.C09	43	49		0.4	Al	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC030001.C09	RC030001.C09	58	9		0.5	Al	
LC040001.C09	RC040001.C09	5	75		0.5	Al	
LC050001.C09	RC050001.C09	6	2		0.5	Al	
LC080001.C09	RC080001.C09	36	3		0.5	Al	
LC080002.C09	RC080002.C09	23	33		0.6	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000007.C09	RE000007.C09	553	937		0.5	Al	
LE000008.C09	RE000008.C09	634	914		0.5	Al	
LE000038.C09	RE000038.C09	1154	-38		0.8	Al	
LE000039.C09	RE000039.C09	794	-3		0.9	Al	*17*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.C09	RE000001.C09	110	873		0.8	Al	*1,2,6*
LE000002.C09	RE000002.C09	352	863		0.5	Al	*2,7*
LE000003.C09	RE000003.C09	63	784		1.0	Al	*1,2*
LE000004.C09	RE000004.C09	100	758		0.3	Al	*2,8*
LE000005.C09	RE000005.C09	119	577		1.1	Al	*1,2*
LE000006.C09	RE000006.C09	377	617		0.5	Al	*2,8*
LE000009.C09	RE000009.C09	758	902		0.7	Al	*3,9*
LE000010.C09	RE000010.C09	833	881		0.6	Al	*3*
LE000011.C09	RE000011.C09	800	769		0.8	Al	*3*
LE000012.C09	RE000012.C09	814	759		0.8	Al	*3*
LE000013.C09	RE000013.C09	623	753		0.7	Al	*3*
LE000014.C09	RE000014.C09	450	760		0.9	Al	*3*
LE000015.C09	RE000015.C09	914	910		0.5	MOS	*5*
LE000016.C09	RE000016.C09	1099	896		0.5	MOS	*5*
LE000017.C09	RE000017.C09	964	832		1.5	MOS	*5,10*
LE000018.C09	RE000018.C09	1252	796		1.2	Al	*5*
LE000019.C09	RE000019.C09	1216	780		0.6	MOS	*5*
LE000020.C09	RE000020.C09	448	758		0.7	Al	*3*
LE000021.C09	RE000021.C09	621	752		0.7	Al	*3*
LE000022.C09	RE000022.C09	458	542		0.5	Al	*3,14*
LE000023.C09	RE000023.C09	457	535		0.6	Al	*3*
LE000024.C09	RE000024.C09	680	605		0.2	Si	*3*
LE000025.C09	RE000025.C09	800	420		0.5	Al	*4,11*
LE000026.C09	RE000026.C09	753	353		0.6	Al	*4*
LE000027.C09	RE000027.C09	714	380		0.6	Si	*4*
AE000027.C09	BE000027.C09	714	380		0.6	Si	*4,15*
LE000028.C09	RE000028.C09	762	208		0.8	Al	*4,11*
LE000029.C09	RE000029.C09	722	178		1.1	Al	*4,b*
LE000030.C09	RE000030.C09	884	684		0.5	MOS	*5*
LE000031.C09	RE000031.C09	1093	715		0.5	MOS	*5*
LE000032.C09	RE000032.C09	1007	646		0.7	MOS	*5*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000033.C09	RE000033.C09	897	259		0.4	MOS	*5*
LE000034.C09	RE000034.C09	475	86		1.0	Al	*4,11,16*
LE000035.C09	RE000035.C09	568	89		0.7	Al	*4*
LE000036.C09	RE000036.C09	1141	131		1.1	MOS	*5*
LE000037.C09	RE000037.C09	38	277		0.8	Al	*1,2*
LE000040.C09	RE000040.C09	945	192		0.5	MOS	*5*
LE000041.C09	RE000041.C09	1001	198		0.5	AL	*5*
LE000042.C09	RE000042.C09	942	49		0.1	MOS	*5,12*
LE000043.C09	RE000043.C09	1178	48		0.5	Al	*5*
LE000044.C09	RE000044.C09	1048	458		0.5	Si	*5,13*
LE000045.C09	RE000045.C09	1130	382		0.3	MOS	*5,18*
LE000046.C09	RE000046.C09	1096	307		0.5	MOS	*5,m*
LE000047.C09	RE000047.C09	263	474		0.5	Al	*2*
LE000048.C09	RE000048.C09	307	432		0.9 x 1.6	Al	*2,8*
LE000049.C09	RE000049.C09	373	239		0.3	Al	*2,8*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

MOS - Metal-oxide-silicon

1 - Impact into aluminum support grid.
2 - Feature located on experiment A0023.
3 - Feature located on experiment A0034.
4 - Feature located on experiment A0114
5 - Feature located on experiment A0201.
6 - Image taken 60° left of normal of crater.
7 - Wrong coordinates (X = 311, Y = 829) input with image file.
8 - Penetration throught aluminum foil.
9 - Wrong coordinates (X = 701, Y = 884) input with image file.
10 - Penetration through MOS Detector.
11 - White painted aluminum surface.
12 - Incomplete spall zone.
13 - Impact into solar array.
14 - Impact into screw.
15 - Lower magnification view of previous image.
16 - Diameter of spall zone = 2.5 mm.
17 - Image taken at 45° from normal of crater.
18 - Possible doublett crater; diameter id of both features together.

OTHER PHOTODOCUMENTATION:

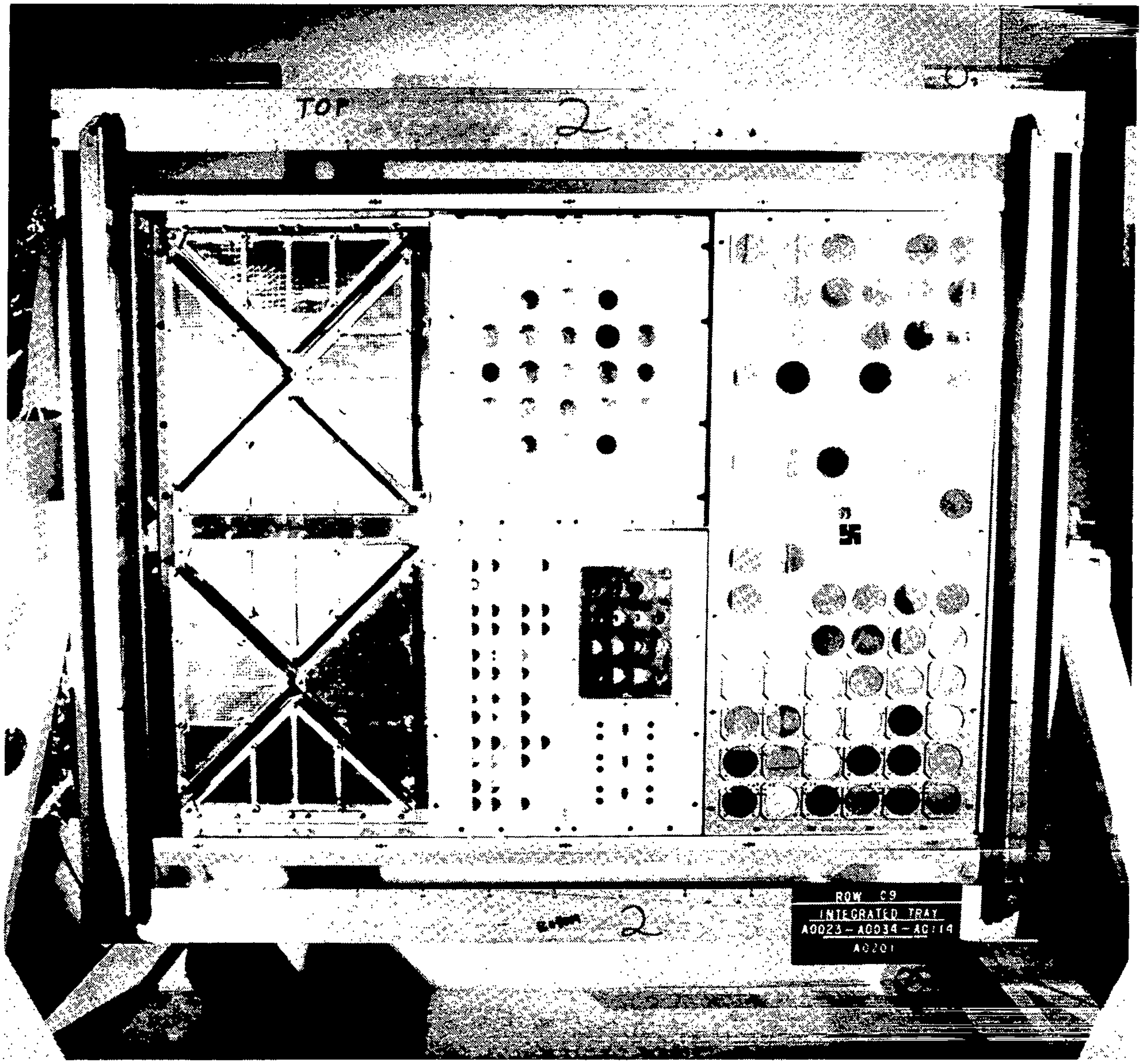
Pre-Flight - 108-KSC-348C-14/3, 108-KSC-348C-14/5, 108-KSC-348C-14/6, 108-KSC-348C-14/7, 108-KSC-348C-14/8
On-Orbit - S32-78-100
Pre-Deintegration - KSC-390C-1030.12, KSC-390C-1031.01, KSC-390C-1030.09
Post Deintegration - KSC-390C-1547.09, KSC-390C-1567.01
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - C09C03, C09C04, C09C05, and C09C08
Clamp Bolts - C09S06A, C09S07B, and C09S07C
Clamp Shims - C09H03

ACCOMPANYING FIGURES:

Figure C09-1. This post-deintegration view shows the front of the entire C09 integrated experiment tray.



LDEF LOCATION: C10
EXPERIMENT IDENTIFICATION: ACTIVE GRAPPLE
PRINCIPAL INVESTIGATOR: SPAR
LDEF PROJECT OFFICE
NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay C10 was occupied by on of the two grapple fixtures, occupying 6"-deep (15.2 cm) trays, which were aboard the LDEF spacecraft. This particular grapple fixture was the active grapple, and was used for giving the initiate signal through the LDEF initiation system to the Experiment Power and Data System (EPDS). The active grapple fixture was designed to allow the EPDS to be shut down for retrieval, but this capability was not used during LDEF's retrieval. The grapple fixture was attached *via* a base (abutment) plate to a 0.125" (3.2 mm) thick 6061-T6 chromic anodized aluminum plate which resided in the bottom of the tray. Next to the grapple fixture was a small array of light emitting diodes (LEDs), which showed the electrical (active) status of the LDEF spacecraft, mounted in a black painted aluminum plate which was mounted flush with the bottom of the grapple tray. Each grapple fixture consisted of an aluminum grapple pin, three brushed aluminum spindles to which the Shuttle Remote Manipulator System (RMS) could attach itself, and an alignment target for the RMS operator to use when grappling the spacecraft. A small (~1" diameter) Teflon button was located at the end of each grapple pin.

All features were typical of craters produced in aluminum during laboratory hypervelocity impact tests. Impacts into the painted surfaces of the grapple fixture caused front surface spallation, and the craters were sometimes surrounded by rings, outside the spallation zones, within which the paint appeared to be slightly raised or "puffed".

On grapple C10, the M&D SIG survey visually identified a total of 958 impact features on all associated experiment-tray surfaces. These surfaces included the tray flanges and walls, the experiment-tray clamps, and the experiment-tray clamp bolts. On the grapple fixture surface, 412 impacts were located. Of these, 400 of the impacts were <0.5 mm in diameter (of which four were photodocumented), 10 were between 0.5 mm and 1.0 mm in diameter (one of which was in the Teflon cap on the grapple pin), and two were between 1.0 mm and 1.5 mm in diameter. Two hundred forty seven impact features were located on the bottom of the grapple tray. Of these, 201 were <0.5 mm in diameter and were not photodocumented (three of which were in the black painted aluminum mount for the LEDs), 36 were between 0.5 mm and 1.0 mm in diameter, five were between 1.0 mm and 1.5 mm in diameter, two were between 1.5 mm and 2.0 mm in diameter, and three were >2.0 mm in diameter. Of the 266 impacts on the experiment-tray flanges and walls, 239 were <0.5 mm in diameter and were not photodocumented (138 of which were located on the tray walls), 27 were between 0.5 mm and 1.0 mm in diameter (12 of which were located on the tray walls), three were between 1.0 mm and 1.5 mm in diameter (of which two were located on the tray walls), and one on the tray wall was between 1.5 mm and 2.0 mm in diameter. On the experiment-tray clamps, 28 of the 33 impacts identified were <0.5 mm in diameter, four were between 0.5 mm and 1.0 mm in diameter, and one was between 1.0 mm and 1.5 mm in diameter.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	28	239	601	868
≥0.5 mm	5	27	58	90
TOTALS	33	266	659	958

The largest impact features identified on tray C10 were (1) an ~1.1 mm diameter crater located on the grapple fixture, (2) an ~2.3 mm diameter crater on the bottom aluminum surface of the grapple tray, (3) an ~1.1 mm diameter crater on the experiment-tray flange, (4) an ~1.6 mm diameter crater in the experiment-tray wall, and (5) an ~1.1 mm diameter crater on an experiment-tray clamp. In addition, one impact ~1.0 mm in diameter was located in the Teflon cap on the grapple pin.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft. This inspection identified 17 features which would be destroyed by emplacement in the experiment-tray rotator. All of these features were <0.5 mm in diameter, and were not included in the summary given above. There were no experiment-tray covers for the grapple trays. One feature each was identified on clamps C02, C04, C05, C06, and C08. The features on clamps C05 and C06 were in locations to warrant concern for damage during bolt removal. The M&D SIG A-Team requested the ground operations personnel to use an open-end wrench when removing bolts C05C and C06B to avoid damaging the features. This request was followed during tray deintegration from LDEF.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

The detailed examination and photodocumentation of experiment-tray C10 was conducted on April 18, 1990 in the vertical position utilizing M&D SIG Systems #1, #2, and #3, and Coordinate Registration System #2. The bolts, clamps and shims associated with this tray were scanned and imaged with M&D SIG System #2; the coordinates for all features on clamps were measured with a metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	68	959	60	-15
Center	626	958	618	-16
Far Right	ND	ND	ND	ND

ND - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC020001.C10	RC020001.C10	36	30		0.7	Al	
LC040001.C10	RC040001.C10	19	21		1.1	Al	
LC050001.C10	RC050001.C10	105	31		0.6 x 0.9	Al	*1,j*
IC060001.C10	JC060001.C10	60	50	1	0.5	Al	*2,18*
AC080001.C10	BC080001.C10	40	4		0.5	Al	*18*

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.C10	RE000001.C10	6	498		1.0	Al	*3*
AE000002.C10	BE000002.C10	-21	501		0.5	Al	*3,4,18*
AE000003.C10	BE000003.C10	-21	671		0.8	Al	*3,4,18*
AE000004.C10	BE000004.C10	-22	907		1.0	Al	*3,4,18*
LE000005.C10	RE000005.C10	416	966		0.7	Al	*3*
LE000006.C10	RE000006.C10	1003	909	90	0.8	Al	*3,f*
CE000007.C10	DE000007.C10	450	920	76	0.8	Al	*3,f,18*
LE000008.C10	RE000008.C10	450	920	76	0.8	Al	*3,f*
LE000009.C10	RE000009.C10	12	866	40	1.6	Al	*3,5,f*
AE000009.C10	BE000009.C10	12	866	40	1.6	Al	*3,5,18,f*
LE000036.C10	RE000036.C10	1260	400		0.6	Al	*6*
LE000037.C10	RE000037.C10	8	223	18	0.7	Al	*6,7,f*
LE000038.C10	RE000038.C10	9	377	60	0.7	Al	*6,8,d,f*
LE000075.C10	RE000075.C10	379	-12		0.8	Al	*9*
LE000076.C10	RE000076.C10	378	-50		1.1	Al	*9*
LE000077.C10	RE000077.C10	391	-50		0.5	Al	*9*
LE000078.C10	RE000078.C10	439	-24		0.7	Al	*9*
LE000079.C10	RE000079.C10	1023	-9		0.5	Al	*9*
LE000080.C10	RE000080.C10	1103	-36		0.6	Al	*9*
LE000081.C10	RE000081.C10	683	23	35	0.5	Al	*9,10,f*
LE000082.C10	RE000082.C10	653	28	90	1.2	Al	*9,10,d,f*
LE000083.C10	RE000083.C10	554	20	78	0.8	Al	*9,10,f*
LE000084.C10	RE000084.C10	491	18	74	0.8	Al	*9,10,f*
LE000085.C10	RE000085.C10	453	4	28	1.3	Al	*9,10,f*
LE000086.C10	RE000086.C10	131	7	38	0.6	Al	*9,10,f*
LE000087.C10	RE000087.C10	420	42	148	0.8	Al	*9,10,f*
LE000088.C10	RE000088.C10	813	34	150	0.5	Al	*9,10,f*
LE000089.C10	RE000089.C10	1073	23	108	0.8	Al	*9,10,f*
LE000090.C10	RE000090.C10	1163	23	100	0.7	Al	*9,10,f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000010.C10	RE000010.C10	61	835		0.7	Al	*3,g*
LE000011.C10	RE000011.C10	124	821		0.6	Al	*3,g*
LE000012.C10	RE000012.C10	120	797		1.9	Al	*3,g*
AE000013.C10	BE000013.C10	193	824		0.6	Al	*3,g,18*
LE000014.C10	RE000014.C10	434	847		0.7	Al	*3,g*
EE000015.C10	FE000015.C10	556	801		1.3	Al	*6,g,18*
LE000016.C10	RE000016.C10	710	874		0.7	Al	*6,g*
LE000017.C10	RE000017.C10	743	829		0.9	Al	*6,g*
LE000018.C10	RE000018.C10	923	739		0.8	Al	*6,g*
AE000019.C10	BE000019.C10	931	747		0.7	Al	*6,g,18*
LE000020.C10	RE000020.C10	1013	694		1.2	Al	*6,g*
LE000021.C10	RE000021.C10	1203	689		0.5	Al	*6,g*
AE000022.C10	BE000022.C10	1143	529		0.7	Al	*6,g,18*
LE000023.C10	RE000023.C10	1193	594		0.5	Al	*6,g*
CE000024.C10	DE000024.C10	1173	669		0.5	Al	*6,g,18*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000025.C10	RE000025.C10	733	739		0.5	Al	*6,11,12*
LE000026.C10	RE000026.C10	953	624		0.3	Al	*6,11*
EE000027.C10	FE000027.C10	958	539		0.9	Al	*3,11,18*
LE000028.C10	RE000028.C10	763	609		0.9	Al	*3,11*
AE000029.C10	BE000029.C10	793	624		0.5	Al	*3,11,13,18*
LE000029.C10	RE000029.C10	793	624		0.5	Al	*3,11,13*
LE000030.C10	RE000030.C10	797	614		0.8	Al	*3,11*
EE000031.C10	FE000031.C10	35	752		1.1	Al	*3,g,18*
LE000032.C10	RE000032.C10	183	741		0.7	Al	*3,g*
LE000033.C10	RE000033.C10	198	527		0.5	Al	*3,g*
CE000034.C10	DE000034.C10	231	552		0.7	Al	*3,g,18*
GE000035.C10	HE000035.C10	579	720		2.0	Al	*6,g,18*
LE000039.C10	RE000039.C10	1123	389		0.5	Al	*6,14*
EE000040.C10	FE000040.C10	1183	449		2.3	Al	*3,g,18*
LE000041.C10	RE000041.C10	1173	429		0.5	Al	*3,g*
LE000042.C10	RE000042.C10	1123	432		0.5	Al	*3,g*
LE000043.C10	RE000043.C10	1118	299		0.8	Al	*3,g*
AE000044.C10	BE000044.C10	1153	359		0.9	Al	*3,18,g*
LE000045.C10	RE000045.C10	988	269		1.5	Al	*3,g*
LE000046.C10	RE000046.C10	810	450		0.6	Al	*3,15*
LE000047.C10	RE000047.C10	790	445		0.9	Al	*3,4,11*
LE000048.C10	RE000048.C10	805	335		0.3	Al	*3,11,13,k*
LE000049.C10	RE000049.C10	908	409		0.6	Al	*3,11*
AE000050.C10	BE000050.C10	996	394		0.1	Al	*1,3,11,18,j,k*
LE000050.C10	RE000050.C10	996	394		0.1	Al	*1,3,11,j,k*
LE000051.C10	RE000051.C10	943	314		1.0 x 1.1	Al	*3,11,j*
CE000052.C10	DE000052.C10	630	400		1.1	Al	*7,9,11,18*
LE000053.C10	RE000053.C10	690	420		1.1	Al	*8,9,16*
LE000054.C10	RE000054.C10	720	470		1.0	Teflon	*9*
LE000055.C10	RE000055.C10	187	429		0.8	Al	*9,g*
LE000056.C10	RE000056.C10	227	266		0.8	Al	*9,17,g*
LE000057.C10	RE000057.C10	242	315		0.6	Al	*9,g*
LE000058.C10	RE000058.C10	305	413		0.6	Al	*9,g*
LE000059.C10	RE000059.C10	374	434		0.7	Al	*9,g*
LE000060.C10	RE000060.C10	359	337		2.0	Al	*9,g*
LE000061.C10	RE000061.C10	468	297		1.0	Al	*9,g*
LE000062.C10	RE000062.C10	80	50		0.6	Al	*9,g*
LE000063.C10	RE000063.C10	100	203		0.5	Al	*9,g*
LE000064.C10	RE000064.C10	154	177		1.1	Al	*9,g*
LE000065.C10	RE000065.C10	208	186		0.7	Al	*9,g*
LE000066.C10	RE000066.C10	250	50		0.6	Al	*9,g*
LE000067.C10	RE000067.C10	371	104		0.5	Al	*9,g*
LE000068.C10	RE000068.C10	381	113		2.0	Al	*9,g*
LE000069.C10	RE000069.C10	534	103		0.7	Al	*9,g*
LE000070.C10	RE000070.C10	665	160		0.7	Al	*9,g*
LE000071.C10	RE000071.C10	802	105		0.5	Al	*9,g*
LE000072.C10	RE000072.C10	1103	209		0.8	Al	*9,g*
LE000073.C10	RE000073.C10	1113	217		0.8	Al	*9,g*
LE000074.C10	RE000074.C10	1193	169		0.5	Al	*9,g*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Possibly two sub-craters within crater.
2 - Impact into edge of clamp.
3 - Image taken using M&D SIG System #1.
4 - Image taken at 30° to right of normal to crater.
5 - Image taken at 45°to left of normal to crater.
6 - Image taken using M&D SIG System #3.
7 - Image taken at 15° to left of normal to crater.
8 - Image taken at 30° to left of normal to crater.
9 - Image taken using M&D SIG System #2.
10 - Image taken at 15° above normal to crater.
11 - Impact into gray painted aluminum base plate of grapple fixture.
12 - Large ring pattern and discoloration zone around crater cannot be seen in image.
13 - Impact crater appeared to be extremely shallow.
14 - Impact into black painted aluminum target plate of grapple fixture.
15 - Impact into brushed aluminum spindle of grapple fixture.
16 - Impact into central polished aluminum plate of grapple fixture.
17 - Wrong Y-coordinate (Y = 226) input into image file.
18 - Prior images are bad due to computer hardware failure.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-383C-4418/6
On-Orbit
Pre-Deintegration - KSC-390C-1028.12, KSC-390C-1029.01, KSC-390C-1029.08
Post Deintegration - KSC-390C-3387.05
M&D SIG Photos - S90-43590 - Feature located on center grapple plate.
S90-43591 - Feature located on center grapple plate.

ARCHIVED MATERIALS:

Clamps - C10C02, C10C04, C10C05, and C10C06

LDEF LOCATION:	**C11**
EXPERIMENT IDENTIFICATION:	**A0178**
EXPERIMENT TITLE:	**A HIGH RESOLUTION STUDY OF ULTRA-HEAVY COSMIC-RAY NUCLEI**
PRINCIPAL INVESTIGATOR:	**D. O'SULLIVAN DUBLIN INSTITUTE FOR ADVANCED STUDIES DUBLIN, IRELAND**

SUMMARY OF OBSERVATIONS

Bay C11 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46" long (~116.8 cm), 10" (25.4 cm) in diameter, 6063-T6 aluminum cylinders (1.9 mm thick) which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with an ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (space facing) of FEP teflon (~120 μm thick) backed with a thin layer of vapor-deposited silver/inconel (~200 to 300 Å thick), which in turn was backed by DC1200 primer and Chemglaze Z306 black conductive paint (~80 to 100 μm thick). The blankets were attached to a 40-5052 aluminum support frame by ~1" x 2" (~2.5 x 5.1 cm) strips of velcro.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of the resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted teflon material. Commonly, the teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. Many possessed several sharp, distinct rings, while other exhibited a more continuous halo phenomenon where the changes from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impact craters into aluminum.

The M&D SIG survey visually identified a total of 508 impact features on the C11 experiment tray, including the experiment-tray clamps and flanges, as well as the thermal insulation blanket. Of these, 392 were found on the thermal blanket, all but a few representing penetrations through the blanket. Three hundred forty four features from the blanket were below the 0.3 mm diameter photodocumentation threshold (eight "Too Smalls" were imaged because they were considered of interest), 47 features were between 0.3 mm and 1.0 mm in diameter, and one feature was photodocumented which was between 1.0 mm and 1.5 mm in diameter. One hundred three features were found on the tray flanges, 92 of which were <0.5 mm in diameter (two "Too Smalls" were imaged because they were considered of interest), 9 of which were between 0.5 mm and 1.0 mm in diameter, and two of which were between 1.0 mm and 1.5 mm in diameter. The remaining 13 features were located while scanning the associated bolts, clamps and shims for experiment-tray C11. All 13 features were <0.5 mm in diameter and were not photodocumented.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			344	344
>0.3 mm			48	48
<0.5 mm	13	92		105
>0.5 mm	0	11		11
TOTALS	13	103	392	508

The largest impact features identified on experiment-tray C11 were (1) an ~1.2 x 1.3 mm penetration hole through the thermal blanket, (2) an ~1.2 mm diameter crater in the experiment-tray flanges, and (3) an ~0.5 mm crater on an experiment-tray clamp.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft. This inspection identified eleven features which might be destroyed by attachment of the experiment-tray cover and four features which would be destroyed by emplacement in the experiment-tray rotator. These latter impact features were estimated to be ~0.5 mm in diameter. These features were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment tray cover and the tray flanges. One feature was identified on clamp C04, and one feature was identified on bolt C06B.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

The detailed examination and photodocumentation of tray C11 was conducted on March 19, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #3. The bolts, clamps and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	58	947	58	-27
Center	616	948	616	-28
Far Right	1174	947	1173	-27

Fiducial Mark Locations (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	215	897	233	26
Center	625	892	594	19
Far Right	1050	892	1012	25

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.C11	RE000001.C11	188	930		0.5	Al	
LE000002.C11	RE000002.C11	507	955		1.2	Al	
LE000003.C11	RE000003.C11	689	925		0.5 x 0.6	Al	
LE000004.C11	RE000004.C11	871	947		1.0	Al	
LE000005.C11	RE000005.C11	924	923		0.7	Al	
LE000033.C11	RE000033.C11	1260	655		0.6	Al	
LE000053.C11	RE000053.C11	1247	229		0.7	Al	
LE000054.C11	RE000054.C11	1257	209		0.5	Al	
LE000055.C11	RE000055.C11	1267	124		0.5	Al	
LE000056.C11	RE000056.C11	993	-17		0.5	Al	
LE000057.C11	RE000057.C11	862	-43		0.6 x 0.7	Al	
LE000058.C11	RE000058.C11	340	-32		0.7	Al	
LE000059.C11	RE000059.C11	129	-20		0.5	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000006.C11	RE000006.C11	44	830		0.3	TB	
LE000007.C11	RE000007.C11	63	874		0.5	TB	
LE000008.C11	RE000008.C11	153	877		1.2 x 1.3	TB	
LE000009.C11	RE000009.C11	69	794		0.2	TB	
LE000010.C11	RE000010.C11	30	678		0.4 x 0.5	TB	
LE000011.C11	RE000011.C11	40	635		0.8	TB	
LE000012.C11	RE000012.C11	189	682		0.5	TB	
LE000013.C11	RE000013.C11	225	681		0.5	TB	
LE000014.C11	RE000014.C11	209	711		0.2 x 0.3	TB	
LE000015.C11	RE000015.C11	230	892		0.5	TB	
LE000016.C11	RE000016.C11	293	899		0.3	TB	
LE000017.C11	RE000017.C11	394	881		0.3 x 0.4	TB	
LE000018.C11	RE000018.C11	509	864		0.4 x 0.5	TB	
LE000019.C11	RE000019.C11	521	750		0.5	TB	
LE000020.C11	RE000020.C11	730	918		0.4	TB	
LE000021.C11	RE000021.C11	741	909		0.3	TB	*d*
LE000022.C11	RE000022.C11	626	667		0.6	TB	*1*
AE000022.C11	BE000022.C11	626	667		0.6	TB	
LE000023.C11	RE000023.C11	635	720		0.3	TB	
LE000024.C11	RE000024.C11	685	658		0.1	TB	*d*
LE000025.C11	RE000025.C11	835	724		0.4 x 0.5	TB	
LE000026.C11	RE000026.C11	879	682		0.4 x 0.5	TB	
LE000027.C11	RE000027.C11	932	736		0.4	TB	
LE000028.C11	RE000028.C11	992	787		0.4 x 0.5	TB	
LE000029.C11	RE000029.C11	1105	848		0.7	TB	
LE000030.C11	RE000030.C11	1178	875		0.4	TB	
LE000031.C11	RE000031.C11	1150	663		0.2	TB	*d*
LE000032.C11	RE000032.C11	1084	695		0.1	TB	*2*
LE000034.C11	RE000034.C11	95	399		0.4	TB	
LE000035.C11	RE000035.C11	103	398		0.4	TB	
LE000036.C11	RE000036.C11	425	437		0.3 x 0.5	TB	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000037.C11	RE000037.C11	382	298		0.3 x 0.4	TB	
LE000038.C11	RE000038.C11	498	369		0.4	TB	
LE000039.C11	RE000039.C11	568	372		0.6 x 0.7	TB	
LE000040.C11	RE000040.C11	577	413		0.3 x 0.4	TB	
LE000041.C11	RE000041.C11	689	439			TB	*3,4*
LE000042.C11	RE000042.C11	689	439		0.3 x 0.5	TB	
LE000043.C11	RE000043.C11	698	442		0.6 x 0.7	TB	
LE000044.C11	RE000044.C11	649	517		0.7 x 0.8	TB	
LE000045.C11	RE000045.C11	814	433		0.5	TB	
LE000046.C11	RE000046.C11	824	603		0.4	TB	
LE000047.C11	RE000047.C11	941	561		0.4	TB	
LE000048.C11	RE000048.C11	931	458		0.5	TB	
LE000049.C11	RE000049.C11	983	333		0.3 x 0.4	TB	
LE000050.C11	RE000050.C11	1094	369		0.5	TB	
LE000051.C11	RE000051.C11	1144	441		0.5	TB	
LE000052.C11	RE000052.C11	1200	506		0.5 x 0.7	TB	
LE000060.C11	RE000060.C11	35	212		0.5	TB	
LE000061.C11	RE000061.C11	31	243		0.5	TB	
LE000062.C11	RE000062.C11	186	27		0.5	TB	
LE000063.C11	RE000063.C11	306	94		0.1	TB	*5*
LE000064.C11	RE000064.C11	382	297		0.4	TB	
LE000065.C11	RE000065.C11	631	23		0.6 x 0.7	TB	
LE000066.C11	RE000066.C11	615	129		0.4	TB	
LE000067.C11	RE000067.C11	780	187		0.5	TB	
LE000068.C11	RE000068.C11	859	159		0.4	TB	
LE000069.C11	RE000069.C11	924	151		0.8	TB	
LE000070.C11	RE000070.C11	1091	258		0.7	TB	*6*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

TB - Thermal Blanket (Teflon, silver-inconel, binder, and paint).

1 - Wrong coordinates (X = 635, Y = 720) input into image file.
2 - Two "Too Smalls" next to each other in image.
3 - Image includes both features imaged separately in #42 and #43.
4 - Wrong coordinates (X = 649, Y = 517) input into image file.
5 - Small oblique impact; coordinates mark the head of the feature.
6 - Wrong magnification (1.2) input into image file, should have been 2.4.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-317/11
On-Orbit - S32-78-42
Pre-Deintegration - KSC-390C-1028.06, KSC-390C-1028.09, KSC-390C-1028.10
Post Deintegration - KSC-390C-2109.09, KSC-390C-2112.03
M&D SIG Photos - S90-43510 and S90-43511 - Left 1/3 of thermal blanket, front and back views.
S90-43512 and S90-43513 - Center 1/3 of thermal blanket, front and back views.
S90-43514 and S90-43515 - Right 1/3 of thermal blanket, front and back views.

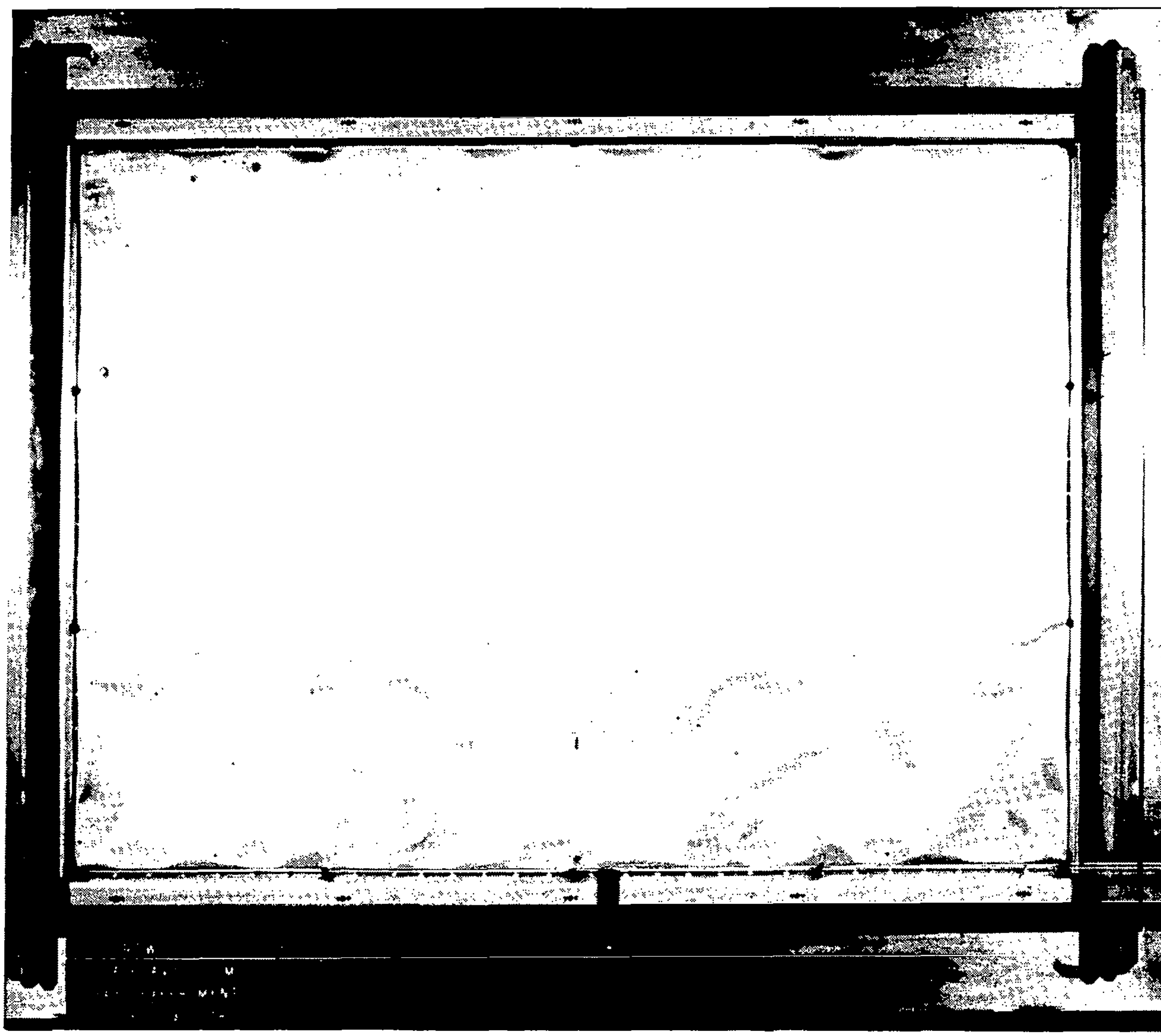
ARCHIVED MATERIALS:

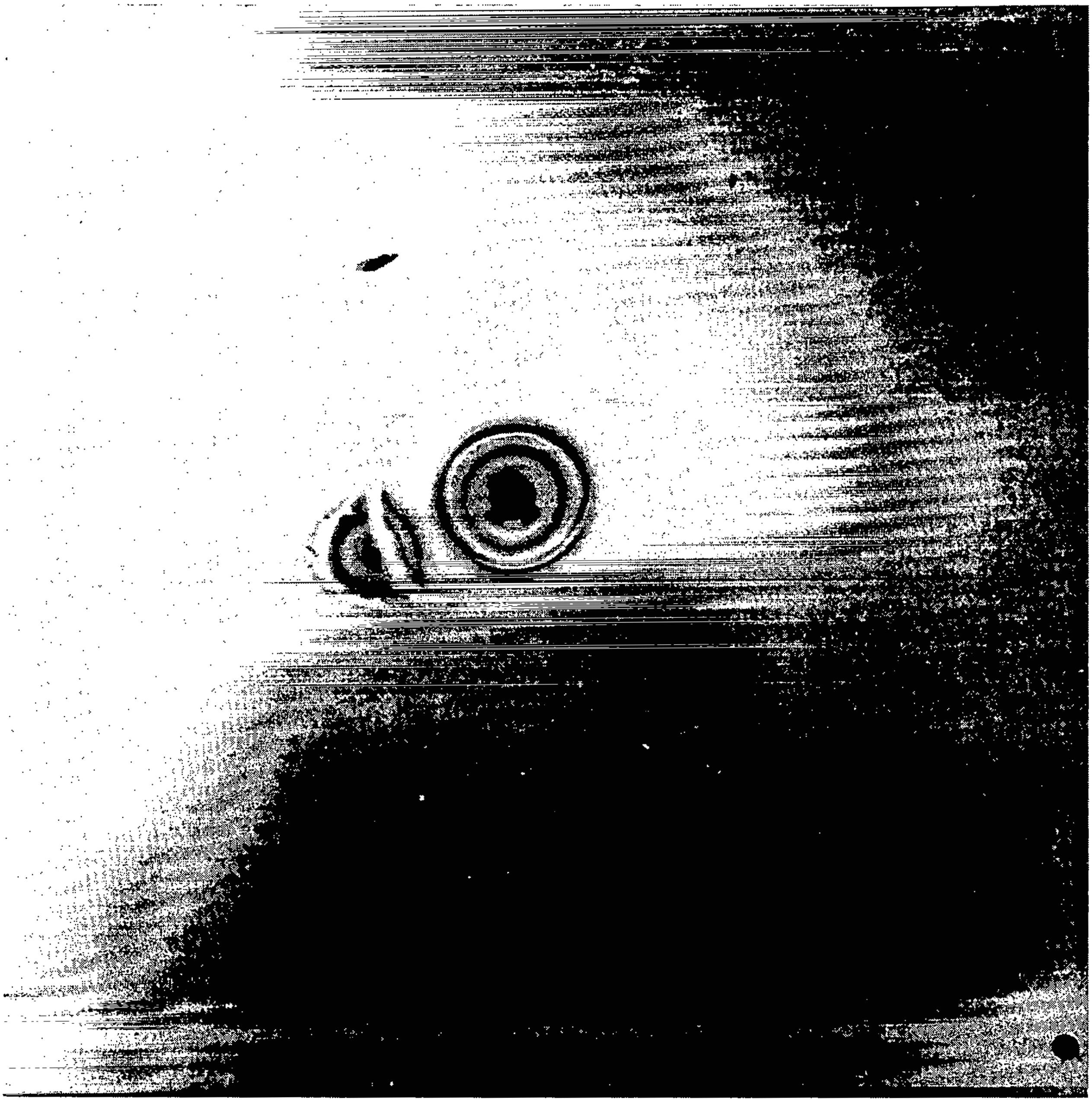
Clamps - C11C01, C11C02, C11C04, and C11C08
Thermal Blanket - (C11E00A) The U.S. third (minus the specimen removed for the Materials SIG) resides at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds (minus the grounding-strap specimen removed for the Materials SIG) are being archived at ESTEC in the Netherlands. Each blanket third was marked with two small crosses (see Fiducial Mark table above) for indexing and reconstruction purposes.

ACCOMPANYING FIGURES:

Figure C11-1. This post-deintegration view shows the front of the entire C11 experiment thermal blanket. Oxygen erosion has given the blanket a frosted appearance. The double impact feature in the center of the blanket is shown in Figure C11.

Figure C11-2. This is a pair of impact penetration features on the C11 thermal blanket, both with concentric rings. The rings of the smaller feature are incomplete, possibly related to the formation of the larger impact feature. View measures approximately 9 cm across.





LDEF LOCATION: C12
EXPERIMENT IDENTIFICATION: S0109
EXPERIMENT TITLE: FIBER OPTIC DATA TRANSMISSION EXPERIMENT
PRINCIPAL INVESTIGATOR: A. JOHNSON
JET PROPULSION LAB
PASADENA, CALIFORNIA

SUMMARY OF OBSERVATIONS

Bay C12 contained a 6"-deep (15.2 cm) active experiment tray that housed the S0109 Fiber Optic Data Transmission Experiment. Experiment S0109 was designed to test fiber optic components in the space environment to determine their ability to operate over long periods of time without degradation of performance. Four fiber cable samples were mounted in a planar helix coil on a white painted thermally isolated mounting plate attached at the tray surface. Six more additional cable samples were mounted on the bottom surface of the tray. Each of the cable samples will be terminated in connectors mounted on brackets. These were located on the back surface of the upper plates, or on the base plates for the internally mounted samples In addition, there was an empty white-painted baseplate occupying the left third of the tray. The coils were numbered 1 to 4, clockwise from the upper left.

Impacts located in the various fiber-optics bundles differed in morphology as a function of the size of the projectile. Smaller and/or lower-velocity projectiles that did not penetrate the plastic coating of the fiber-optics cables resembled craters produced in polymers under laboratory hypervelocity conditions. Such craters commonly possess a raised rim of melted plastic and a pit or crater exhibiting a smooth, melted morphology. Projectiles of sufficient mass and/or velocity that penetrated the fiber-optics coating generally produced a penetration-hole type morphology in the fiber-optics coating material. The optical fibers varied in their degree of damage from simple breakage and splintering, to various degrees of melting; such features generally exhibited a relatively rough or irregular crater shape. Several features were examined that represented complete penetrations through the edge of a fiber-optics bundle. Such features commonly possessed a roughly circular or hemispherical outline, while the polymer coatings and optical fibers exhibited morphologies similar to those previously described.

All aluminum surfaces on the S0109 experiment were painted. Features examined in these surfaces displayed interesting morphological characteristics, commonly exhibiting a ringed appearance. Virtually all features >0.2 mm in diameter possessed a spall zone in which all of the paint was removed from the aluminum surface. Such spall zones varied in size from approximately two to five crater diameters (similar responses of painted aluminum surfaces were documented on the four LDEF scuff plates). The actual craters in the aluminum substrate varied from central pits without raised rims, to morphologies more typical of craters formed in aluminum under hypervelocity, laboratory condition for the larger features. Most of the features possessed what was termed a "shock zone" by the M&D SIG A-Team. These zones varied in size from approximately one to as much as 30 crater diameters. In most cases, only the outer-most layer of the paint was effected by this impact related phenomenon. Several impacts possessed ridge-like structures ringing the area in which this outer-most paint layer was removed. In many ways, such features resembled basin-sized lunar craters, but on an extremely reduced scale. Lastly, several features were noted in the painted aluminum surfaces immediately around the fiber-optics bundles that were nearly identical in appearance to the penetration features on the various A0178 thermal blankets (*i.e.*, multiple-ringed features). This multiple-ringed morphology for craters was found only on a few of the surfaces flown on the LDEF spacecraft (*e.g.*, the abutment plate of the C10 active grapple fixture). As with the other painted aluminum surface previously described, a paint spall zone was commonly found in association with the central pit or crater Around this spall zone was an area of discoloration varying in size from five to ten spall-zone diameters. At least one of

these areas appeared as though the outer-most layer of the paint had been removed. The remaining rings (2 to ~10) appeared as little more than discolorations in the paint.

The M&D SIG survey identified a total of 272 features on all surfaces of the C12 experiment tray. Of the 272 features identified as being <0.5 mm in diameter, 30 resided on the experiment-tray flanges, 30 were on the various clamps associated with the C12 tray, and 198 were counted from the painted aluminum surfaces and fiber-optics bundles. Thirteen features were photodocumented, of which three were on a fiber-optic bundles, five resided on the painted aluminum surfaces, four were found on the experiment-tray flanges, and one feature was located on clamp C02; all but two of these features ranged from 0.4 to 1.0 mm in diameter. The remaining two features were 1.2 mm and 1.0 mm in diameter located in the experimental-tray flange.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	30	30	198	258
>0.5 mm	1	4	9	14
TOTALS	31	34	207	272

The largest impact feature found on experiment-tray C12 measured ~1.2 mm in diameter located on the experimental-tray flange. Three impact features were found in the fiber optic bundles.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft and identified two features that might be damaged by the placement of the experiment-tray cover over the surface of the experiment. Although these two features were identified, no alterations to the gasket was necessary.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges or spallation features on the 0.125" (3.2 mm) experiment-tray flanges or backside.

DOCUMENTATION:

Examination and photodocumentation of experiment-tray C12 was conducted on March 21, 1990 in the vertical position utilizing M&D SIG System #1. The bolts, clamps and shims associated with this tray were scanned with M&D SIG System #3. All coordinates for features residing on these materials were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC020001.C12	RC020001.C12	86	10		0.7 x 2.8	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000009.C12	RE000009.C12	743	-15		0.8	Al	
LE000010.C12	RE000010.C12	448	-12		1.2	Al	
LE000011.C12	RE000011.C12	273	-40		0.6	Al	
LE000012.C12	RE000012.C12	1122	7	25	1.0	Al	*1*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.C12	RE000001.C12	825	740		0.7	Al Baseplate	
LE000002.C12	RE000002.C12	1180	700		0.8	FO Coil #2	*2*
LE000003.C12	RE000003.C12	1180	700		0.4	FO Coil #2	
LE000004.C12	RE000004.C12	175	335		0.7	Al(painted)	*3*
LE000005.C12	RE000005.C12	75	185		0.6	Al(painted)	*3*
LE000006.C12	RE000006.C12	464	87		0.6 x 0.8	Al(painted)	*4*
LE000007.C12	RE000007.C12	550	197		0.6 x 1.4	FO Coil #3	
LE000008.C12	RE000008.C12	870	153		0.6	Al(painted)	*5*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

FO - Fiber Optic.

1 - Image was rotated 50° clockwise.
2 - Feature may not be an impact.
3 - ~1.8 mm paint delamination zone surrounds the impact feature.
4 - ~1.5 mm paint delamination zone surrounds the impact feature.
5 - ~1.1 mm paint delamination zone surrounds the impact feature.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-348C-300/1
On-Orbit - S32-89-048
Pre-Deintegration - KSC-390C-1069.04, KSC-390C-1069.05, KSC-390C-1069.11
Post Deintegration - KSC-390C-2204.02
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - C12C01, C12C02, C12C03, and C12C08
Clamp Bolts - C12S02A
Clamp Shims - C12H07
Other - Plastic experiment-tray baseplate, painted white, from left third of experiment-tray E01.

LDEF LOCATION:	**D01**
EXPERIMENT IDENTIFICATION:	**A0178**
EXPERIMENT TITLE:	**A HIGH-RESOLUTION STUDY OF ULTRA-HEAVY COSMIC-RAY NUCLEI**
PRINCIPAL INVESTIGATOR:	**D. O'SULLIVAN** **DUBLIN INSTITUTE FOR ADVANCED STUDIES** **DUBLIN, IRELAND**

SUMMARY OF OBSERVATIONS

Bay D01 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46"-long (116.8 cm), 10" (25.4 cm) diameter aluminum cylinders which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with a ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (facing space) of FEP Teflon (~120 μm thick) backed with a thin layer of silver-inconel (~200 to 300 Å thick), which in turn is backed by Chemglaze Z306 black conductive paint and binding medium (~80 to 100 μm thick). The structure and attachments for the experiment tray consisted of the tray flanges and walls (0.125" [3.2 mm] thick chromic anodized 6061-T6 aluminum), the experiment-tray clamps (0.19" [4.8 mm] thick chromic anodized 6061-T6 aluminum), and the experiment-tray clamp bolts (303 stainless steel). The backs of the trays were also covered with a reflective thermal blanket.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted Teflon material. Commonly, the Teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. When impacts occurred into the velcro which supported the thermal blanket materials, large delamination areas were very common around the penetration. Many penetrations possessed several sharp, distinct, colored rings, while others exhibited a more continuous halo phenomenon where the change from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impacts into aluminum.

The M&D SIG survey identified a total of 163 features on the D01 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the thermal insulation blanket. Of these, 141 were found on the thermal blanket, all but a few representing penetrations through the blanket. One hundred and thirty features from the blanket were below the 0.3 mm diameter photodocumentation threshold. One image photodocuments which two small features within the same field of view, both possessing diameters <0.3 mm. Only 11 features were between 0.3 mm and 1.0 mm in diameter and were photodocumented. Fifteen features were identified on the tray flanges, two of which were located on the portion of the experiment-tray flanges underlying the tray-stand clamps and could not be examined during the detail inspection. However, the diameters for these features were estimated during the initial tray inspection to be ~0.2 mm and ~1.0 mm, respectively. All but one of the other 13 features found within the tray flange areas were <0.5 mm in diameter

and not photodocumented. The remaining seven features were located while scanning the associated bolts, clamps, and shims associated with tray D01 and all were <0.5 mm in diameter. One feature each was found on clamps C02 and C05, two features were found on clamp C08, one of which was located on the edge of the clamp, and three features were identified on clamp C06.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			130	130
>0.3 mm			11	11
<0.5 mm	7	13		20
>0.5 mm		2		2
TOTALS	7	15	141	163

The largest impact feature identified was an ~0.9 mm penetration hole in the thermal blanket.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection (February 21, 1990) was conducted while the experiment tray was mounted on the spacecraft and identified only four features which might be damaged by the emplacement of the experiment-tray cover and only two features which could be damaged or destroyed by placing the experiment tray within the experiment-tray rotator stand. In an effort to protect the most interesting feature within the experiment-tray cover area, the cover gasket was cut in one location to prevent the cover from coming into contact with this feature and to provide a stand-off for the experiment-tray cover and the tray flanges. One feature residing on the side of clamp C08 was identified, while two features were found on clamp C06.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of tray D01 was conducted on March 26, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #3. The bolts, clamps, and shims associated with this tray were scanned with M&D SIG System #1.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	60	947	59	-27
Center	618	947	616	-27
Far Right	1176	947	1175	-27

Fiducial Mark Locations (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Left	211	888	203	23
Middle	608	885	594	22
Right	1043	879	1012	29

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000012.D01	RE000012.D01	1139	-19		0.6	Al	*1*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.D01	RE000001.D01	223	744		0.3	TB	
LE000002.D01	RE000002.D01	329	789		0.4	TB	*2*
LE000003.D01	RE000003.D01	766	774		0.4	TB	
LE000004.D01	RE000004.D01	997	854		0.2	TB	*3*
LE000005.D01	RE000005.D01	1142	514		0.4 x 0.6	TB	
LE000006.D01	RE000006.D01	1120	596		0.9	TB	
LE000007.D01	RE000007.D01	924	646		0.3	TB	
LE000008.D01	RE000008.D01	636	227		0.4	TB	
LE000009.D01	RE000009.D01	551	337		0.6 x 0.7	TB	
LE000010.D01	RE000010.D01	585	72		0.5	TB	
LE000011.D01	RE000011.D01	1037	105		0.3	TB	
LE000013.D01	RE000013.D01	721	336		0.4	TB	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

TB - Thermal Blanket (Teflon, silver-inconel, binder, and paint)

1 - Wrong coordinates (X = 997, Y = 854) input with image file.
2 - Wrong magnification (2.4X) entered with image.
3 - Two features within the field of view.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-373/4
On-Orbit - S32-89-042
Pre-Deintegration - KSC-390C-1069.01, KSC-390C-1069.03, KSC-390C-1066.09
Post Deintegration - KSC-390C-2284.04
M&D SIG Photos - S90-43541, S90-43542 - Left 1/3 of Thermal Blanket; front and back view.
S90-43543, S90-43544 - Center 1/3 of Thermal Blanket; front and back view.
S90-43545, S90-43546 - Right 1/3 of Thermal Blanket; front and back view.

ARCHIVED MATERIALS:

Clamps - D01C02, D01C05, D01C06, and D01C08
Thermal Blanket - (D01E00A) - The U.S. third (minus the Materials SIG specimen) reside at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds are being archived at ESTEC in The Netherlands. Each blanket third was marked with two small crosses (see Fiducial Mark table above) for indexing and reconstruction purposes.

LDEF LOCATION:	**D02**
EXPERIMENT IDENTIFICATION:	**S0001**
EXPERIMENT TITLE:	**SPACE DEBRIS IMPACT EXPERIMENT**
PRINCIPAL INVESTIGATOR:	**D. HUMES 493 NASA LANGLEY RESEARCH CENTER HAMPTON, VIRGINIA 23665**
	A0189 STUDY OF FACTORS DETERMINING THE RADIATION SENSITIVITY OF QUARTZ CRYSTAL OSCILLATORS J. VENABLES MARTIN MARIETTA BALTIMORE, MARYLAND
	A0172 EFFECTS OF SOLAR RADIATION ON GLASSES D. TUCKER NASA MARSHALL SPACE FLIGHT CENTER HUNTSVILLE, ALABAMA

SUMMARY OF OBSERVATIONS

Bay D02 contained a 3"-deep (7.6 cm), integrated, passive experiment tray which housed one meteoroid and debris experiment (S0001), one experiment designed to study the radiation sensitivity of quartz crystal oscillators (A0189), and one designed to study the effects of solar radiation on glasses (A0172).

Experiment S0001 was designed to establish the population and size distribution of meteoroids in the mass range from 10^{-10} to 10^{-4} grams, to establish the current population of man-made debris in the same mass range, and to obtain data on the physical properties of meteoroids. Bay D02 held one of the 3"-deep (7.6 cm), partial (2/3) passive peripheral trays which were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed nineteen full peripheral trays and three end-corner trays (two on the Earth end and one on the space end). Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located in all rows except Row 9, the leading-edge direction.

The A0189 experiment was designed to determine whether there is a correlation between defect cluster concentrations observed for different grades of quartz examined by Transmission Electron Microscopes (TEM), and the electrical stability of quartz resonators exposed to the complex radiation associated with an orbital LDEF environment. The experiment hardware was contained in one-sixth of this 3"-deep (7.6 cm) peripheral tray. At-cut resonators, fabricated from two materials (synthetic swept premium Q and Brazilian natural quartz) were mounted on an aluminum plate and attached to tray D02.

The A0172 experiment was designed to determine the effects of solar radiation and space environment on glasses in space flight by exposing glass specimens to the space environment and analyzing the optical, mechanical, and chemical property changes which occur. The property changes of samples receiving differing

cumulative solar radiation exposure will be compared. This experiment was conducted by passively exposing glass samples occupying one-sixth of this 3"-deep (7.6 cm) tray located near the trailing edge of the LDEF so that they would be exposed to a maximum amount of incident solar radiation. This location contained 68 cylindrical disc samples 1.25" (3.2 cm) in diameter. Another group of 52 samples occupying one-fourth of a 3"-deep (7.6 cm) tray was located on the Earth-facing end of LDEF and received minimum exposure to solar radiation. Sample compositions include aluminosilicates, fused silica, titanium silicate, lead silicates, borosilicates, soda potash lime, potash borosilicate, and soda lime silica glasses.

The M&D SIG survey identified a total of 37 features on the D02 experiment tray including the experiment-tray bolts, clamps, shims, and flanges. Of the 37 impacts found, 33 features were <0.5 mm in diameter. Four of these features were located on the experiment-tray clamps and bolts, nine were located on the experiment-tray flanges, and 20 were located on the three experimental surfaces (ten on S0001, six on A0172, and four on A0189). Three of these features located on experiment A0172 ranged in diameter from 0.1 mm to 0.4 mm and were imaged because they were of interest. One of these features located on experiment A0189 was ~0.2 mm in diameter and was also imaged. Of the remaining four features, one was located on the experiment-tray flange and measured ~0.8 mm in diameter. The three remaining impacts were located on the experimental surfaces, two of which were located on experiment S0001 and measured ~0.5 mm and ~0.6 mm in diameter, respectively, while the remaining feature was located on experiment A0189 and was ~1.0 mm in diameter.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	4	9	20	33
>0.5 mm		1	3	4
TOTALS	4	10	23	37

The largest impact feature found on this tray measured ~1.0 mm in diameter, was located on the A0189 experiment, and was an apparent multiple impact feature. We documented some small features because they were into interesting substrates (quartz and glass), or exhibited large spall or delamination features.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection (February 21, 1990) was conducted while the experiment tray was mounted on the spacecraft and identified no features which might be damaged by the attachment of the experiment-tray cover but located one feature which could be damaged or destroyed by placing the experiment tray within the experiment-tray rotator stand. This feature was not examined or documented, nor was it included in the numerical summary given above. The impacts found on the tray flange were on the outer part so no gaskets had to be cut to provide protection.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges or spallation features on the 0.0625" (1.6 mm) thick experiment-tray flanges or backside.

DOCUMENTATION:

Examination and photodocumentation of tray D02 was conducted on March 16, 1990 in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #3. The bolts, clamps, and shims associated with this tray were scanned with M&D SIG System #3; the coordinates for features residing on these materials were measured with a small metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000007.D02	RE000007.D02	238	-35		0.8	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.D02	RE000001.D02	328	770		0.4	Quartz #7	*4,6*
LE000002.D02	RE000002.D02	380	328		0.1	Glass #22	*1,4*
LE000003.D02	RE000003.D02	543	225		0.6	Al	*3*
LE000004.D02	RE000004.D02	1065	445		0.5	Al	*3*
LE000005.D02	RE000005.D02	265	895		0.2	Brown Paint	*2,5*
LE000006.D02	RE000006.D02	420	860		1.0	Al	*5,j*
AE000006.D02	BE000006.D02	420	860		1.0	Al	*5,j*
LE000008.D02	RE000008.D02	117	117		0.4	Al	*4*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - ~0.4 mm diameter spall feature is present.
2 - ~0.8 mm diameter spall (delamination?) feature is present.
3 - Feature located on experiment S0001.
4 - Feature located on experiment A0172.
5 - Feature located on experiment A0189.
6 - Image taken at 45° from normal to crater.

OTHER PHOTODOCUMENTATION:

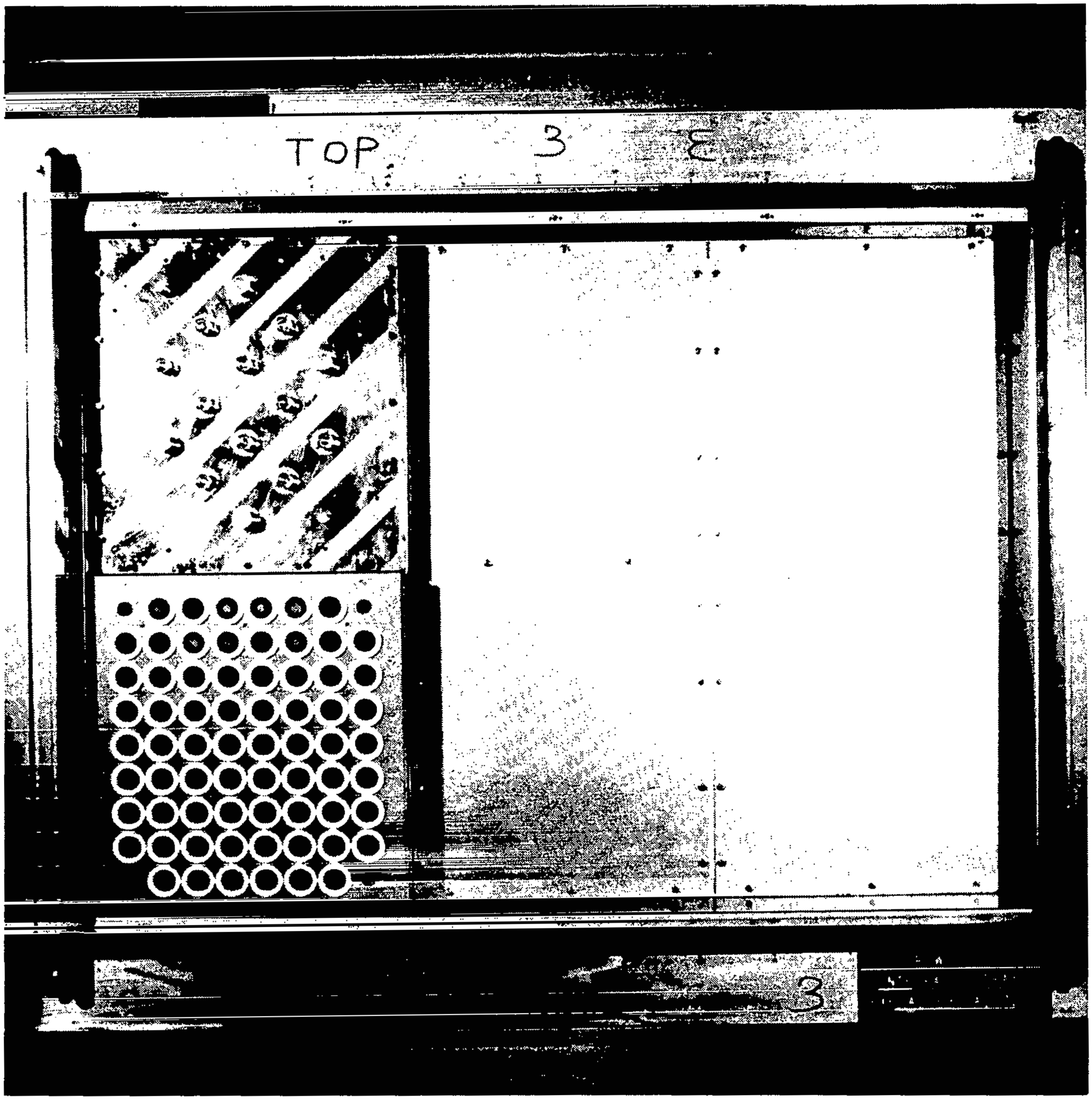
Pre-Flight - L-84-7158, 108-KSC-384C-317/1
On-Orbit - S32-89-13
Pre-Deintegration - KSC-390C-1065.07, KSC-390C-1065.09, KSC-390C-1066.01, KSC-390C-1066.02
Post Deintegration - KSC-390C-1036.07, KSC-390C-2038.05, KSC-390C-2038.04
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - D02C02, D02C04, D02C06, and D02C08

ACCOMPANYING FIGURES:

Figure D02-1. This post-deintegration view shows the front of the entire D02 integrated experiment tray.


TOP
3
3

LDEF LOCATION: D03
EXPERIMENT IDENTIFICATION: M0002
EXPERIMENT TITLE: TRAPPED-PROTON ENERGY SPECTRUM DETERMINATION
PRINCIPAL INVESTIGATOR: G. FISHMAN
NASA MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

M0003
SPACE ENVIRONMENTAL EFFECTS ON SPACECRAFT MATERIALS
M. MESHISHNEK
THE AEROSPACE CORPORATION
EL SEGUNDO, CALIFORNIA

SUMMARY OF OBSERVATIONS

Bay D03 contained a 3"-deep (7.6 cm), integrated, passive experiment tray which housed two experiments: M0003 designed to study space exposure effects on spacecraft materials, and M0002 designed to study ion fluxes with energies greater than 1 MeV.

The M0002 experiment was designed to measure the flux and energy spectrum of protons with energies of 1 to 10 MeV. The M0002-1 tray is a passive experiment which occupied 25 percent of this 3"-deep (7.6 cm) peripheral tray. The experiment consists of six stacks of passive plastic detectors (CR-39) arranged in portions of three LDEF trays located in Bays D09, D03, and G12. The stacks are 1.49" (3.8 cm) square and 2.60" (6.6 cm) high. They are mounted in containers arranged in the trays to be normal to the Earth's magnetic field in the South Atlantic. The bottom half of each stack is composed of CR-39 without DOP and is 0.022" (0.56 mm) thick. The next 40 percent of the stack is CR-39 with DOP and is 0.022" (0.56 mm) thick. The top 10 percent of the stack is CR-39 with CHCP and is 0.011" (0.28 mm) thick. The top layer of plastic is directly exposed to space. A sheet of aluminum 0.001" (25 μm) thick separates each layer of plastic.

The M0003 experiment was designed to study the changes in the properties and structure of materials after exposure to the space environment and to compare these changes with predictions based on laboratory experiments. The M0003 experiment occupied 75 percent of this 3"-deep (7.6 cm) peripheral tray and consisted of 19 subexperiments involving a number of DOD laboratories and contractor organizations. The hardware consists of four peripheral trays (D03, D04, D08, and D09), two experiment power and data systems (EPDS), two experiment exposure control canisters (EECC), and LiO_2 batteries to satisfy power requirements. Tray D03 contained a variety of thermal control coatings, composites, laser optics electronic piece parts, fiber optics, and solar cells.

The M&D SIG survey identified a total of 13 features on the D03 experiment tray including the experiment-tray bolts, clamps, shims, and flanges. Of these, two were imaged on the experiment-tray flanges and were both >1.0 mm in diameter. Eight impact features were documented on the experiment-tray surfaces (of which all but one were located on M0003) and ranged in diameter from 0.4 to 1.8 mm. Six of these were penetrations through thin mylar films. As with all LDEF trays containing thin film materials, the threshold documentation diameter was 0.3 μm to take into account the difference between cratering and penetration phenomena. Two features <0.5 mm were found on the experiment-tray clamps and were not photodocumented. A complete survey for impacts below the documentation cut-off size was not performed.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm				@
>0.3 mm			4	4
<0.5 mm	2		1	3@
>0.5 mm		2	4	6
TOTALS	2	2	9	13@

@ Survey for "Too Smalls" was incomplete.

The two largest impact features found on this tray were 1) a circular impact ~1.8 mm in diameter located on the experiment-tray flange and 2) a penetration hole measuring ~1.8 mm in diameter with aluminized mylar film being the substrate.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

An initial inspection of this tray was performed on February 20, 1990, while the experiment tray was attached to the spacecraft, in order to document features which might be altered during tray deintegration. No such features were located, although two features were identified on the experiment-tray flanges and two were found on clamp C08.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick, chromic-anodized, 6061-T6 experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of tray D03 was conducted on February 28, 1990 in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #3. The bolts, clamps, and shims associated with this tray were scanned with M&D SIG System #3; the coordinates for features residing on these materials were measured with a small metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000008.D03	RE000008.D03	205	-30		1.1	Al	
LE000009.D03	RE000009.D03	230	-40		1.0	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.D03	RE000001.D03	90	905		0.9	Al	*4*
LE000002.D03	RE000002.D03	220	560		0.4	Film	*1,4*
LE000003.D03	RE000003.D03	220	560		0.5	Film	*1,4*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000004.D03	RE000004.D03	280	540		0.3 x 0.4	Film	*1,4*
LE000005.D03	RE000005.D03	60	250		0.5	Film	*1,2*
LE000006.D03	RE000006.D03	1040	560		1.8	Al	*3,4*
LE000007.D03	RE000007.D03	335	180		0.3	Film	*1,4*
LE000010.D03	RE000010.D03	108	45		1.8	Film	*1,4*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Diameter given is of the penetration hole.
2 - This penetration has a raised feature surrounding the hole measuring ~1.2 mm in diameter; ejecta recoil?.
3 - Impact feature located on M0002.
4 - Impact feature located on M0003.

OTHER PHOTODOCUMENTATION:

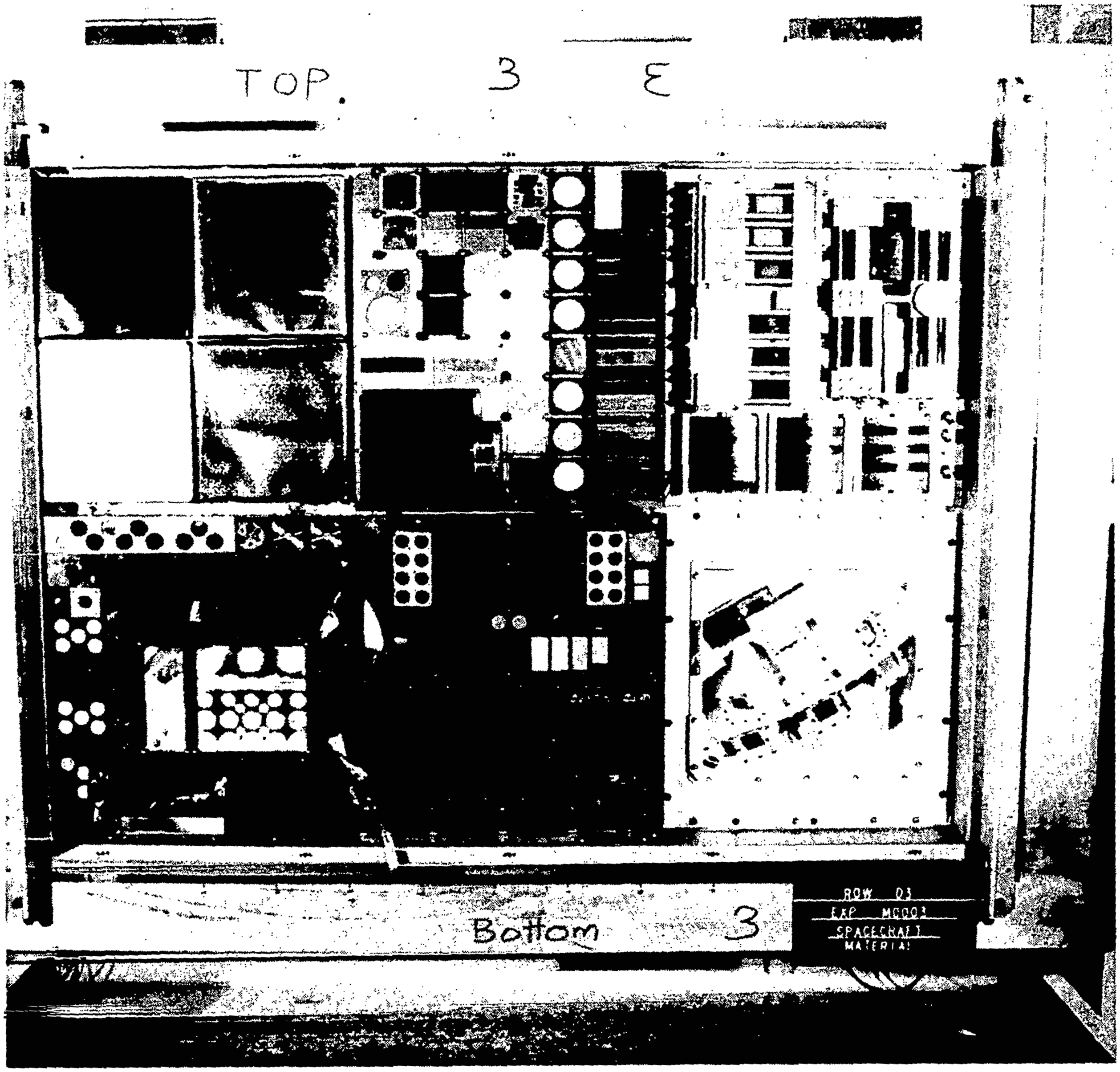
Pre-Flight - 108-KSC-348C-210/4
On-Orbit - S32-89-008
Pre-Deintegration - KSC-390C-1065.01, KSC-390C-1065.03, KSC-390C-833.11
Post Deintegration - KSC-390C-1485.05, KSC-390C-1004.04, KSC-390C-1004.07
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - D03C06 and D03C08

ACCOMPANYING FIGURES:

Figure D03-1. This post-deintegration view shows the front of the entire D03 experiment tray.


TOP.
3
E
Bottom
3
ROW 03
EXP M0003
SPACECRAFT
MATERIAL

LDEF LOCATION: D04
EXPERIMENT IDENTIFICATION: M0003
EXPERIMENT TITLE: SPACE ENVIRONMENTAL EFFECTS ON SPACECRAFT MATERIALS
PRINCIPAL INVESTIGATOR: M. MESHISHNEK
THE AEROSPACE CORPORATION
EL SEGUNDO, CALIFORNIA

SUMMARY OF OBSERVATIONS

The M0003 experiment was designed to study the changes in the properties and structure of materials after exposure to the space environment and to compare these changes with predictions based on laboratory experiments. The M0003 experiment, located in Bay D04, occupied a full 6"-deep (15.2 cm) peripheral tray. The M0003 experiment consisted of 19 subexperiments involving a number of DOD laboratories and contractor organizations. The hardware consists of four peripheral trays (D03, D04, D08, and D09), two experiment power and data systems (EPDS), two experiment exposure control canisters (EECC), and LiO_2 batteries to satisfy power requirements. Tray D04 contained a variety of thermal control coatings, composites, laser optics electronic piece parts, fiber optics, and solar cells. This tray also held one of the active EECCs, which automatically opened and then closed during the LDEF mission. The M&D SIG was not permitted to open and survey the interior of the EECC at Kennedy Space Center.

The M&D SIG survey identified a total of 19 features on the D04 experiment tray including the experiment-tray bolts, clamps, shims and flanges. Of the 19 impacts found, 12 features, located on the experiment-tray surface, did not meet the 0.5 mm diameter criteria for impact craters and were not imaged. The survey of "Too Smalls" for this tray was not completed. Of the seven impacts which were imaged, all but one were located on the M0003 experiment surface and ranged in size between 0.5 mm to 0.8 mm in diameter; one of these impacts was a penetration ~0.7 mm in diameter. The only other impact imaged on tray D04 was ~0.6 mm in diameter and was located on the lower experiment-tray flange. There were no impacts found on the experiment-tray clamps or bolts. The interior exposed surfaces and samples of the EECC were not examined by the M&D SIG A-Team. Impact features residing in the various aluminum hardware associated with tray D04 were typical of hypervelocity impacts into aluminum produced under laboratory conditions.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm			12	12@
>0.5 mm		1	6	7
TOTALS		1	18	19@

@ Survey for "Too Smalls" was incomplete.

The largest impact feature found on this tray measured ~0.8 mm in diameter and was located on the M0003 experiment surface.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection (February 22, 1990) was conducted while the experiment tray was mounted on the spacecraft and identified five features which might be damaged by the attachment of the experiment-tray cover and one additional feature which could be damaged or destroyed by placing the experiment tray within the

experiment-tray rotator stand. This latter feature was not examined or photodocumented, nor was it included in the numerical summary given above. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of tray D04 was conducted on February 28, 1990 in the vertical position utilizing M&D SIG System #2. The bolts, clamps and shims associated with this tray were scanned with M&D SIG System #3. The coordinates for all features were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000006.D04	RE000006.D04	460	-20		0.6	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.D04	RE000001.D04	215	360		0.5	Al	
LE000002.D04	RE000002.D04	880	650		0.5	Al	
LE000003.D04	RE000003.D04	50	480		0.5	Al	
LE000004.D04	RE000004.D04	490	950		0.8	Al	
LE000005.D04	RE000005.D04	1280	920		0.5	Al	
LE000007.D04	RE000007.D04	450	90		0.7	Film	*1*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Penetration diameter.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-210/1
On-Orbit - S32-89-004
Pre-Deintegration - KSC-390C-1065.06, KSC-390C-1065.05, KSC-390C-832.04
Post Deintegration
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - D04C02, D04C03, D04C05, and D04C07

LDEF LOCATION: D05
EXPERIMENT IDENTIFICATION: A0178
EXPERIMENT TITLE: A HIGH RESOLUTION STUDY OF ULTRA-HEAVY COSMIC-RAY NUCLEI
PRINCIPAL INVESTIGATOR: D. O'SULLIVAN
DUBLIN INSTITUTE FOR ADVANCED STUDIES
DUBLIN, IRELAND

SUMMARY OF OBSERVATIONS

Bay D05 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46"-long (116.8 cm), 10" (25.4 cm) diameter aluminum cylinders which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with a ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (facing space) of FEP Teflon (~120 μm thick) backed with a thin layer of silver-inconel (~200 to 300 Å thick), which in turn is backed by Chemglaze Z306 black conductive paint and binding medium (~80 to 100 μm thick). The structure and attachments for the experiment tray consisted of the tray flanges and walls (0.125" [3.2 mm] thick chromic anodized 6061-T6 aluminum), the experiment-tray clamps (0.19" [4.8 mm] thick chromic anodized 6061-T6 aluminum), and the experiment-tray clamp bolts (303 stainless steel). The backs of the trays were also covered with a reflective thermal blanket.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted Teflon material. Commonly, the Teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. When impacts occurred into the velcro which supported the thermal blanket materials, large delamination areas were very common around the penetration. Many penetrations possessed several sharp, distinct, colored rings, while others exhibited a more continuous halo phenomenon where the change from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impacts into aluminum.

The M&D SIG survey visually identified a total of 266 impact features on the D05 experiment tray, including the experiment-tray clamps and flanges, as well as the thermal insulation blanket. Of these, 238 were found on the thermal blanket, all but a few representing penetrations through the blanket. Two hundred twenty eight features from the blanket were below the 0.3 mm diameter photodocumentation threshold (two "Too Smalls" were imaged because they were considered of interest), and 10 features were between 0.3 mm and 1.0 mm in diameter. Twenty four features were found on the tray flanges, 20 of which were <0.5 mm in diameter (one "Too Small" was imaged because it was considered of interest), 2 of which were between 0.5 mm and 1.0 mm in diameter, one of which was between 1.0 mm and 1.5 mm in diameter, and one of which was an ejecta spray pattern which could not be photodocumented. The remaining four features were located while scanning the

associated bolts, clamps, and shims for tray D05. All four features were <0.5 mm in diameter and were not photodocumented.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			228	228
>0.3 mm			10	10
<0.5 mm	4	20		24
>0.5 mm		4		4
TOTALS	4	24	238	266

The largest impact features identified were (1) an ~0.5 x 0.8 mm penetration hole through the thermal blanket, (2) an ~1.1 mm diameter crater in the experiment-tray flanges, and (3) an ~0.4 mm crater on an experiment-tray clamp. A total of 16 features were photodocumented from tray D05.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 22, 1990 while the experiment tray was mounted on the spacecraft. This inspection identified three features which might be destroyed by attachment of the experiment-tray cover and three features which would be destroyed by emplacement in the experiment-tray rotator. These latter impact features were estimated to be <0.5 mm in diameter. These latter features were not examined or photodocumented, nor were they included in the numerical summary given above. No cuts were made in the cover gasket. One feature was identified on clamp C08, and one was identified on the side of bolt S06B. The M&D SIG A-Team requested the Ground Operations personnel to use an open-end wrench to remove this bolt to avoid damaging the crater. This request was followed during the tray removal procedures.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

The detailed examination and photodocumentation of tray D05 was conducted on March 22, 1990 in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #1. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Fiducial Mark Locations (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	235	905	235	21
Center	616	905	617	26
Far Right	1004	888	1006	23

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000004.D05	RE000004.D05	-12	613		0.5	Al	
LE000014.D05	RE000014.D05	313	-51		1.1	Al	*d*
AE000014.D05	BE000014.D05	313	-51		1.1	Al	*d*
LE000015.D05	RE000015.D05	665	-8		0.1	Cu/Al	*1*
LE000016.D05	RE000016.D05	1043	-20		0.5	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.D05	RE000001.D05	676	885		0.5 x 0.8	TB	
LE000002.D05	RE000002.D05	535	683		0.4	TB	
LE000003.D05	RE000003.D05	1063	601		0.3	TB	
LE000005.D05	RE000005.D05	356	495		0.5	TB	
LE000006.D05	RE000006.D05	401	462		0.4	TB	
LE000007.D05	RE000007.D05	457	570		0.5	TB	
LE000008.D05	RE000008.D05	929	522		0.5	TB	
LE000009.D05	RE000009.D05	1037	488		0.3	TB	
AE000009.D05	BE000009.D05	1037	488		0.3	TB	
LE000010.D05	RE000010.D05	930	40		0.4	TB	*2*
LE000011.D05	RE000011.D05	342	12		0.5	TB	
LE000012.D05	RE000012.D05	168	197		0.3	TB	*3*
LE000013.D05	RE000013.D05	77	100		0.5	TB	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

TB - Thermal Blanket (Teflon, silver-inconel, binder, and paint)

1 - Impact feature was into copper grounding strap from thermal blanket to tray flanges, with spray onto aluminum grounding strap connector below grounding strap.
2 - This impact feature had no rings surrounding it.
3 - Wrong coordinates (X = 77, Y = 100) input into image file.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-60/2
On-Orbit - S32-82-17
Pre-Deintegration - KSC-390C-1035.06, KSC-390C-1035.10, KSC-390C-1035.12
Post Deintegration - KSC-390C-2277.10
M&D SIG Photos - S90-43533 - Left 1/3 of thermal blanket, angled front view.
S90-43531 and S90-43532 - Center 1/3 of thermal blanket, angled front and backlit back views.
S90-43529 and S90-43530 - Right 1/3 of thermal blanket, angled front and backlit back views.

ARCHIVED MATERIALS:

Clamps - D05C04, D05C05, D05C07, and D05C08
Clamp Bolts - D05S06B
Thermal Blanket - (D05E00A) - The U.S. third (minus the specimen removed for the Materials SIG) resides at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds (minus the grounding-strap specimen removed for the Materials SIG) are being archived at ESTEC in the Netherlands. Each blanket third was marked with two small crosses (see Fiducial Mark table above) for indexing and reconstruction purposes.
Other - D05E01 - Aluminum grounding strap connector.
LD-32 - Core from copper grounding strap containing feature #15 (D05E00, 15).
LD-87 - Core from aluminum grounding strap connector containing feature #15 spray (D05E01,15).

LDEF LOCATION:	**D06**
EXPERIMENT IDENTIFICATION:	**S0001**
EXPERIMENT TITLE:	**SPACE DEBRIS IMPACT EXPERIMENT**
PRINCIPAL INVESTIGATOR:	**D. HUMES** **493 NASA LANGLEY RESEARCH CENTER** **HAMPTON, VIRGINIA 23665**
	A0201 **INTERPLANETARY DUST EXPERIMENT** **F. SINGER** **UNIVERSITY OF VIRGINIA** **CHARLOTTESVILLE, VIRGINIA**

SUMMARY OF OBSERVATIONS

Bay D06 was an integrated 3"-deep (7.6 cm) tray, holding parts of experiments S0001 and A0201. The left two thirds of tray D06 held one of 22 passive experiment trays composing the S0001 experiment. This section of the tray contained two 1/8" (3.2 mm) thick sheets of clear anodized aluminum. The S0001 experiment exposed an identical material in 22 different positions on LDEF. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The right third of tray D06 held experiment A0201, another dedicated interplanetary dust (and space debris) experiment. This experiment employed metal-oxide-silicon (MOS) capacitor-type impact sensors, each measuring approximately 50 mm in diameter.

The impact features observed on the aluminum surfaces of experiment S0001 were typical hypervelocity craters. Generally, impact features into the MOS detectors exhibited a central depression surrounded by a spallation zone. Fractures or cracks radiating from the central depression were commonly found in association with the larger impacts into the amorphous metal-oxide-silicon detector material.

The M&D SIG survey identified a total of 207 features on the D06 experiment tray including the experiment-tray bolts, clamps, shims, and flanges. Of the 207 impacts found, 184 features were <0.5 mm in diameter. Nine of these features were located on the experiment-tray clamps and bolts, 38 were located on the tray flanges, and the remaining 137 were located on the experiment-tray surface. Four of these latter 137 features were imaged, three due to their large (>1.0 mm) spall zones in the MOS detectors and one because it was an oblique multi-cratering impact event. Of the remaining 23 imaged features, one was located on the experiment-tray flange and measured ~0.6 mm in diameter. One impact feature was located on the experiment-tray bolt and washer S04A, and was ~0.8 mm in diameter. The 21 remaining impacts were located on the experimental surfaces of S0001 and A0201. Thirteen of these impacts were located on experiment S0001 and ranged in diameter from 0.5 mm to 0.8 mm. Eight of these impacts were located on experiment A0201 and ranged in diameter from 0.6 mm to 1.0 mm. Impact features residing in the various aluminum hardware associated with each of the two experiments on D06 were typical of hypervelocity impacts into aluminum produced under laboratory conditions.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	9	38	137	184
>0.5 mm	1	1	21	23
TOTALS	10	39	158	207

The largest impact feature found on this tray measured ~1.0 mm in diameter and was located on one of the MOS detectors. No large impacts were located on the tray clamps, however one large (~0.8 mm diameter) impact into a clamp bolt and washer (S04A) deposited an ejecta spray onto its associated clamp (C04)

M&D SIG INSPECTION

PRE-DEINTEGRATION:

An initial inspection of this tray was performed on February 22, 1990 while the experiment tray was mounted on the spacecraft in order to document features which might be altered during the tray deintegration process. One feature was identified which could be damaged by attachment of the experiment-tray cover and one which would be damaged or destroyed by placing the experiment tray within the experiment-tray rotator stand. This latter feature was not examined or photodocumented, nor was it included in the numerical summary given above. One was also identified on the clamp C04 bolt and washer S04A. The M&D SIG A-Team requested the Ground Operations personnel to use an open-end wrench to remove this bolt to avoid damaging the crater. This request was followed during the tray removal procedures.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of tray D06 was conducted on March 16, 1990 in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #1. The bolts, clamps, and shims associated with this tray were scanned with M&D SIG System #3, and impact coordinates on these were determined using a small metric scale.

Bolt Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	68	959	66	-16
Middle	627	958	624	-17
Far Right	1186	957	1182	-17

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LS040001.D06	RS040001.D06	0	5		0.8	Steel	*1*

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000026.D06	RE000026.D06	1112	-39		0.6	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.D06	RE000001.D06	27	902		0.5	Al	*14*
LE000002.D06	RE000002.D06	162	946		0.3	Al	*2,14,d,j*
LE000003.D06	RE000003.D06	205	924		0.6	Al	*14*
LE000004.D06	RE000004.D06	46	768		0.8	Al	*14*
LE000005.D06	RE000005.D06	1013	723		0.4	MOS	*3,15*
LE000006.D06	RE000006.D06	120	690		0.6	Al	*14*
LE000007.D06	RE000007.D06	344	303		0.6	Al	*14*
LE000008.D06	RE000008.D06	37	437		0.7	Al	*14*
LE000009.D06	RE000009.D06	446	594		0.6	Al	*14*
LE000010.D06	RE000010.D06	545	563		0.5	Al	*14*
LE000011.D06	RE000011.D06	745	525		0.6 x 0.8	Al	*2,14,d*
LE000012.D06	RE000012.D06	725	427		0.6	Al	*14*
LE000013.D06	RE000013.D06	1194	681		0.7 x 0.9	MOS	*4,15*
LE000014.D06	RE000014.D06	1197	642		0.8	MOS	*5,6,15*
AE000014.D06	BE000014.D06	1197	642		0.8	MOS	*5,6,15*
LE000015.D06	RE000015.D06	945	564		0.9	MOS	*7,15*
AE000015.D06	BE000015.D06	945	564		0.9	MOS	*7,15*
LE000016.D06	RE000016.D06	1120	572		1.0	MOS	*8,15*
LE000017.D06	RE000017.D06	1216	525		0.9	MOS	*9,15*
AE000017.D06	BE000017.D06	1216	525		0.9	MOS	*9,15*
LE000018.D06	RE000018.D06	945	438		0.9	MOS	*10,15*
AE000018.D06	BE000018.D06	945	438		0.9	MOS	*10,15*
LE000019.D06	RE000019.D06	1140	300		0.8	MOS	*11,15*
LE000020.D06	RE000020.D06	1135	318		0.4	MOS	*12,15*
LE000021.D06	RE000021.D06	844	235		0.6 x 0.8	Al	*2,15*
LE000022.D06	RE000022.D06	894	95		0.3	MOS	*13,15*
LE000023.D06	RE000023.D06	762	129		0.5	Al	*15*
LE000024.D06	RE000024.D06	648	10		0.8	Al	*15*
LE000025.D06	RE000025.D06	343	113		0.9	Al	*15*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

MOS - Metal-oxide-silicon capacitor-type impact sensor

1 - The impact onto this washer deposited ejecta onto associated clamp C04.
2 - Possible oblique impact.
3 - Row 4, cell 3 MOS surface.
4 - Row 4, cell 6 MOS.
5 - Row 5, cell 6 MOS.
6 - Penetration hole measures ~0.3 mm in diameter.
7 - Row 6, cell 2 MOS; surface exhibits an ~2.3 x 0.7 mm chip.

8 - Row 6, cell 5 MOS.
9 - Row 7, cell 4 MOS; ~4.3 mm diameter spall ring about impact crater.
10 - Row 8, cell 2 MOS; ~3.8 mm spall ring; ~0.3 mm penetration hole.
11 - Row 10, cell 5 MOS; ~0.4 mm penetration hole.
12 - Row 10, cell 5 MOS; ~2.0 mm spall feature.
13 - Row 13, cell 1 MOS; ~1.2 mm spall feature.
14 - Feature located on the S0001 experiment.
15 - Feature located on the A0201 experiment.

OTHER PHOTODOCUMENTATION:

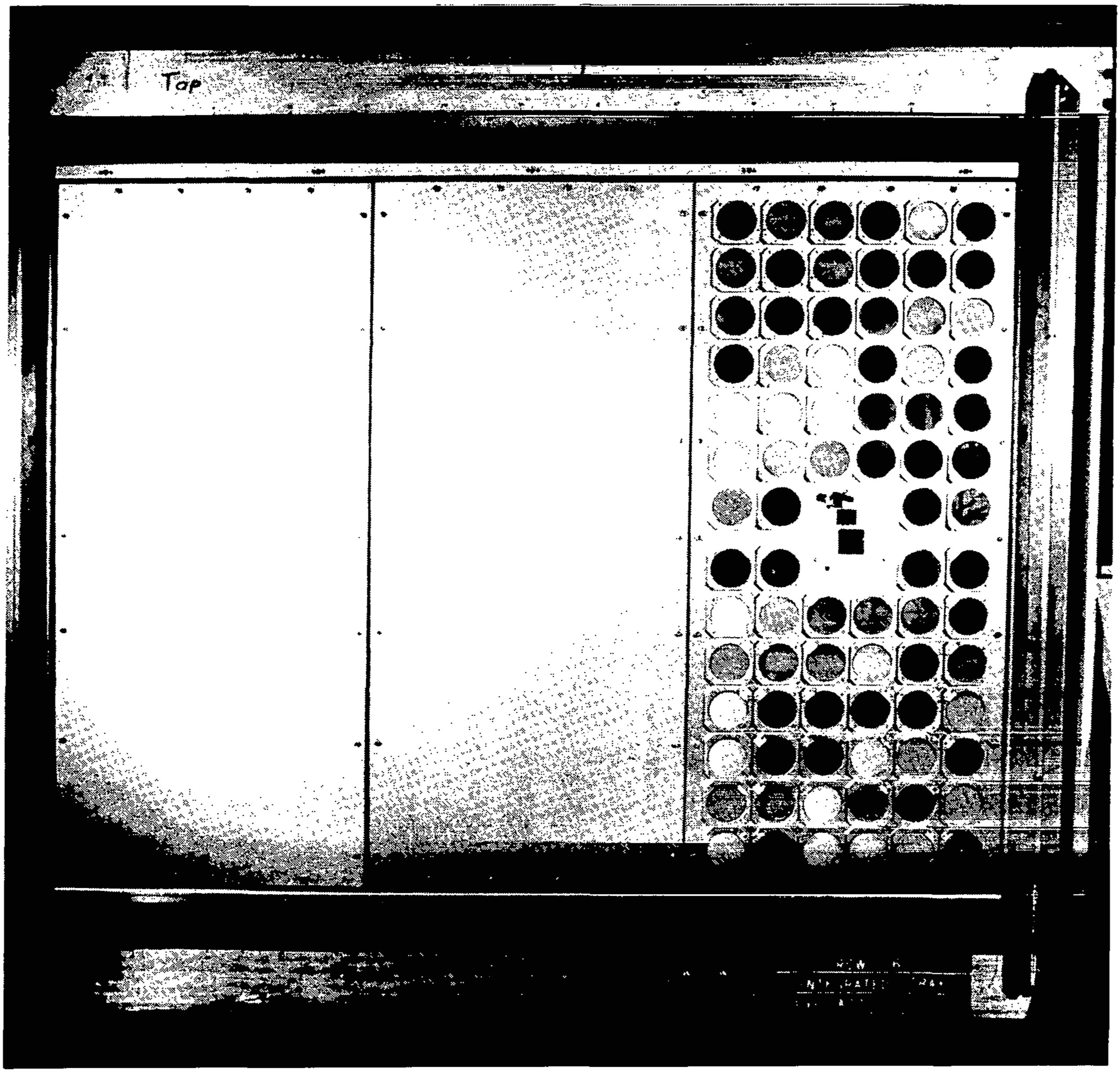
Pre-Flight - 108-KSC-384C-15/10
On-Orbit - S32-82-9, S32-82-44
Pre-Deintegration - KSC-390C-1033.11, KSC-390C-1033.03, KSC-390C-1033.10
Post Deintegration - KSC-390C-2070.10
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - D06C03, D06C04, D06C05, and D06C08
Clamp Bolts (and Washers) - D06S04A, D06S04C
Clamp Washers - D06S06A

ACCOMPANYING FIGURES:

Figure D06-1. This post-deintegration view shows the front of the entire D06 experiment tray.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LDEF LOCATION: D07
EXPERIMENT IDENTIFICATION: A0178
EXPERIMENT TITLE: A HIGH RESOLUTION STUDY OF ULTRA-HEAVY COSMIC-RAY NUCLEI
PRINCIPAL INVESTIGATOR: D. O'SULLIVAN
DUBLIN INSTITUTE FOR ADVANCED STUDIES
DUBLIN, IRELAND

SUMMARY OF OBSERVATIONS

Bay D07 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46"-long (116.8 cm), 10" (25.4 cm) diameter aluminum cylinders which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with a ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (facing space) of FEP Teflon (~120 μm thick) backed with a thin layer of silver-inconel (~200 to 300 Å thick), which in turn is backed by Chemglaze Z306 black conductive paint and binding medium (~80 to 100 μm thick). The structure and attachments for the experiment tray consisted of the tray flanges and walls (0.125" [3.2 mm] thick chromic anodized 6061-T6 aluminum), the experiment-tray clamps (0.19" [4.8 mm] thick chromic anodized 6061-T6 aluminum), and the experiment-tray clamp bolts (303 stainless steel). The backs of the trays were also covered with a reflective thermal blanket.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted Teflon material. Commonly, the Teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. When impacts occurred into the velcro which supported the thermal blanket materials, large delamination areas were very common around the penetration. Many penetrations possessed several sharp, distinct, colored rings, while others exhibited a more continuous halo phenomenon where the change from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impacts into aluminum.

The M&D SIG survey visually identified a total of 415 impact features on the D07 experiment tray, including the experiment-tray clamps and flanges, as well as the thermal insulation blanket. Of these, 320 were identified as "Too Smalls" being less than the 0.3 mm or the 0.5 mm photodocumentation thresholds. However, the M&D SIG A-Team did not identify the locations of these "Too Small" features, (*i.e.*, thermal blanket or tray flanges). Of the total impact features, 76 were definitely found on the thermal blanket, all but a few representing penetrations through the blanket. Eighteen features from the blanket were below the 0.3 mm diameter photodocumentation threshold (five "Too Smalls" were imaged because they were considered of interest), and 58 features were between 0.3 mm and 1.0 mm in diameter. Three features were found on the tray flanges, two of which were <0.5 mm in diameter (one "Too Small" was imaged because it was considered of interest), and one of which was between 1.0 mm and 1.5 mm in diameter. The remaining 16

features were located while scanning the associated bolts, clamps, and shims for tray D07. Twelve of these features were <0.5 mm in diameter (two "Too Smalls" were imaged because they were considered of interest), three were between 0.5 mm and 1.0 mm in diameter, and one was between 1.0 mm and 1.5 mm in diameter.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm				18*
>0.3 mm			58	58
<0.5 mm	12			334*
>0.5 mm	4	1		5
TOTALS	16			415*

* The location of the "Too Smalls" was not documented.

The largest impact features identified were (1) an ~0.7 x 1.0 mm penetration hole through the thermal blanket, (2) an ~1.3 mm diameter crater in the experiment-tray flanges, and (3) an ~1.2 mm crater on an experiment-tray clamp. A total of 71 features were photodocumented from tray D07.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 22, 1990 while the experiment tray was mounted on the spacecraft. This inspection identified eight features which might be destroyed by attachment of the experiment-tray cover and two features which would be destroyed by emplacement in the experiment-tray rotator. Of these latter impact features, one was estimated to be <0.5 mm in diameter, and one was estimated to be ~1.5 mm in diameter. These features were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges. Fourteen features were identified on the D07 experiment-tray clamps, and one feature was identified on bolt S01B.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.125" (3.2 mm) thick experiment-tray flanges. There were gouges on the back of the tray flanges which indicated sideways movement. There was also a yellow-brown discoloration on the gray aluminum parts on the ends of the experiment tray. This discoloration started at the bottom corners of the tray (near LDEF Row 8) and angled up the sides of the experiment tray at ~30-50°. The discoloration seemed to come from the holes in the blankets at the corners and fanned out along the sides of the experiment tray.

DOCUMENTATION:

The detailed examination and photodocumentation of tray D07 was conducted on February 26 and 27, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #1. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	63	948	57	-27
Center	621	943	615	-32
Far Right	1180	939	1172	-35

Fiducial Mark Locations - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC020001.D07	RC020001.D07	32	3		0.7	Al	*1*
LC040001.D07	RC040001.D07	34	35		0.4	Al	*1*
LC040002.D07	RC040002.D07	47	58		0.5	Al	*1*
LC050001.D07	RC050001.D07	41	29		0.5	Al	*1*
LC050002.D07	RC050002.D07	114	24		1.2	Al	*1,2*
LC070001.D07	RC070001.D07	14	2		0.7	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.D07	RE000001.D07	-9	761		0.5	Al	*3*
LE000002.D07	RE000002.D07	1131	934		1.3	Al	*4*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000003.D07	RE000003.D07	21	816		0.3	TB	
LE000004.D07	RE000004.D07	122	873		0.2, 0.2	TB	*5*
LE000005.D07	RE000005.D07	123	783		0.5	TB	
LE000006.D07	RE000006.D07	422	782		0.3	TB	*4,6,7*
LE000007.D07	RE000007.D07	502	841		0.3	TB	*4*
LE000008.D07	RE000008.D07	565	898		0.6	TB	*4*
LE000009.D07	RE000009.D07	685	692		0.4	TB	*4,8*
LE000010.D07	RE000010.D07	714	697		0.4	TB	*4,8*
LE000011.D07	RE000011.D07	847	841		0.4	TB	*4,8*
LE000012.D07	RE000012.D07	839	783		0.4	TB	*4*
LE000013.D07	RE000013.D07	904	772		0.4	TB	*4*
LE000014.D07	RE000014.D07	930	873		0.5	TB	*4*
LE000015.D07	RE000015.D07	1155	892		ND	TB	*5,9*
LE000016.D07	RE000016.D07	77	536		0.4	TB	
LE000017.D07	RE000017.D07	81	351		0.3 x 0.5	TB	
LE000018.D07	RE000018.D07	103	326		0.5	TB	
LE000019.D07	RE000019.D07	60	279		0.5	TB	
LE000020.D07	RE000020.D07	43	233		0.8	TB	
LE000021.D07	RE000021.D07	168	674		0.2, 0.1	TB	*5*
LE000022.D07	RE000022.D07	217	648		0.4	TB	*6*
LE000023.D07	RE000023.D07	211	451		0.5	TB	*6*
LE000024.D07	RE000024.D07	344	656		0.3, 0.2	TB	*5*
LE000025.D07	RE000025.D07	395	513		0.3	TB	*10*
AE000025.D07	BE000025.D07	395	513		0.3	TB	*10*
LE000026.D07	RE000026.D07	269	431		0.6	TB	
LE000027.D07	RE000027.D07	310	379		0.3	TB	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000028.D07	RE000028.D07	419	325		0.3	TB	
LE000029.D07	RE000029.D07	378	277		0.3, 0.2	TB	*5,k*
LE000030.D07	RE000030.D07	370	195		0.3	TB	
LE000031.D07	RE000031.D07	530	552		0.3	TB	
LE000032.D07	RE000032.D07	507	551		0.3	TB	
LE000033.D07	RE000033.D07	495	278		0.3, 0.1	TB	*5*
LE000034.D07	RE000034.D07	568	271		0.5	TB	
LE000035.D07	RE000035.D07	585	265		0.5	TB	
LE000036.D07	RE000036.D07	471	200		0.5	TB	
LE000037.D07	RE000037.D07	469	170		0.4	TB	
LE000038.D07	RE000038.D07	683	692		0.5	TB	
LE000039.D07	RE000039.D07	712	697		0.5	TB	
LE000040.D07	RE000040.D07	761	224		0.6	TB	
LE000041.D07	RE000041.D07	903	717		0.3	TB	
LE000042.D07	RE000042.D07	837	681		0.4	TB	
LE000043.D07	RE000043.D07	839	631		0.7	TB	
LE000044.D07	RE000044.D07	889	516		0.3	TB	
LE000045.D07	RE000045.D07	850	321		0.4	TB	
LE000046.D07	RE000046.D07	966	213		0.4	TB	
LE000047.D07	RE000047.D07	1144	702		0.5	TB	
LE000048.D07	RE000048.D07	1159	718		0.4	TB	
LE000049.D07	RE000049.D07	1049	565		0.7 x 1.0	TB	
LE000050.D07	RE000050.D07	1114	569		0.3	TB	
LE000051.D07	RE000051.D07	1079	520		0.4	TB	
LE000052.D07	RE000052.D07	1073	485		0.2, 0.2	TB	*5*
LE000053.D07	RE000053.D07	1124	309		0.4	TB	
LE000054.D07	RE000054.D07	270	151		0.7	TB	
LE000055.D07	RE000055.D07	369	195		0.4	TB	
LE000056.D07	RE000056.D07	344	36		0.5, 0.4	TB	*5,k*
LE000057.D07	RE000057.D07	408	116		0.4	TB	
LE000058.D07	RE000058.D07	639	153		0.8	TB	
LE000059.D07	RE000059.D07	762	119		0.3	TB	
LE000060.D07	RE000060.D07	876	34		0.4	TB	*11*
LE000061.D07	RE000061.D07	907	120		0.4	TB	*12*
LE000062.D07	RE000062.D07	920	110		0.5	TB	
LE000063.D07	RE000063.D07	1013	137		0.3	TB	
LE000064.D07	RE000064.D07	1178	23		0.3	TB	
LE000065.D07	RE000065.D07	1068	53		0.5	TB	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined
TB - Thermal Blanket (Teflon, silver-inconel, binder, and paint)

1 - Coordinates input into image in centimeters instead of millimeters.
2 - Crater is distorted from being near the washer for bolt S05C.
3 - Image taken at 45° below normal of crater.
4 - Image taken at 55° below normal of crater.
5 - Two features visible in image; diameters given are for largest, smallest.
6 - Cracks emanating from penetration.

7 - Delamination around penetration ~5.8 mm in diameter.
8 - Delamination around penetration ~1.5 cm in diameter.
9 - No diameters recorded for either feature.
10 - Wrong diameter (~0.62 mm) input into image file.
11 - Rings around penetration are non-circular.
12 - Wrong Y coordinate (Y = 110) input into image file.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-371/11
On-Orbit - S32-82-50
Pre-Deintegration - KSC-390C-1032.04, KSC-390C-1032.08, KSC-390C-1032.10
Post Deintegration - KSC-390C-1472.01, KSC-390C-1472.02
M&D SIG Photos - S90-43479 and S90-43480 - Left 1/3 of thermal blanket, straight-on and backlit front views.
S90-43490 - Left 1/3 of thermal blanket after removing 4" wide section for Materials SIG.

ARCHIVED MATERIALS:

Clamps - D07C03, D07C04, D07C05, and D07C07
Thermal Blanket - (D07E00A) - The U.S. third (minus the specimen removed for the Materials SIG) resides at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds are being archived at ESTEC in the Netherlands. The blanket sections were not marked for indexing and reconstruction purposes.

ACCOMPANYING FIGURES:

Figure D07-1. This post-deintegration view shows the front of the entire D07 experiment thermal blanket.


1
Top

LDEF LOCATION: D08
EXPERIMENT IDENTIFICATION: M0003
EXPERIMENT TITLE: SPACE ENVIRONMENT EFFECTS ON SPACECRAFT MATERIALS

PRINCIPAL INVESTIGATOR: M. MESHISHNEK
THE AEROSPACE CORPORATION
EL SEGUNDO, CALIFORNIA

SUMMARY OF OBSERVATIONS

Bay D08 is one of four whole or partial trays which make up the Space Environment Effects on Spacecraft Materials experiment. This whole 6"-deep (15.2 cm) experiment tray was dedicated to experiment M0003; the other M0003 trays were D09 and D03 (5/6 of each tray was M0003), and D04 (the whole tray). The M0003 experiment consists of 19 subexperiments involving a number of Department of Defense laboratories and contractors, with the purpose of understanding the changes in the properties and structure of materials after exposure to the space environment in order to improve performance and usage of existing materials. The M0003 experiment hardware for Bay D08 consists of an Experiment Power and Data System (EPDS) which fills 1/3 of the tray, an Experiment Exposure Control Canister (EECC) which fills another 1/3 of the tray, $LiSO_2$ batteries to provide experiment power, a signal conditioning electronics box which fills 1/6 of the tray, and 1/6 of the tray contained samples of various materials (including composites, metals, and paints). M0003 also carried control specimens (inside the tray and behind the exposed specimens) which would only be exposed to the spacecraft's thermal cycling. The aluminum covers on the EPDS and the signal conditioning electronics box were painted with white thermal control paint. The experiment samples were mounted in a chromic anodized aluminum plate. The EECC was programmed to open in three stepped intervals to vary the ultraviolet light exposure of the samples. The first 1/3 incremental opening occurred ~10 days after LDEF deployment, the second 1/3 increment was programmed to occur approximately 3 months later, and the final 1/3 opening was programmed to occur another 3 months later. The EECC was programmed to close prior to LDEF retrieval. The EPDS was programmed to record data periodically (every ~107 hours for one orbit) over a span of 15 months.

Morphologically, impacts into metals were typical of craters produced during controlled laboratory hypervelocity impact tests. Impacts into painted samples created a front surface spall zone surrounding the crater, with a larger outer ring within which the paint was "puffed" up.

On experiment tray D08, the M&D SIG survey visually identified a total of 99 impact features on all associated experiment-tray surfaces. These surfaces included the tray flanges and walls (0.125" [3.2 mm] thick chromic anodized 6061-T6 aluminum), the experiment-tray clamps (0.19" [4.8 mm] thick chromic anodized 6061-T6 aluminum), and the experiment-tray clamp bolts (303 stainless steel). The tray was not surveyed for impacts <0.5 mm in diameter. In addition, the interior exposed surfaces and samples of the EECC were not examined by the M&D SIG A-Team. On the experiment surfaces, 64 impacts were located. Of these, 34 of the impacts were <0.5 mm in diameter (seven were photodocumented as they were considered to be of interest), 27 were between 0.5 mm and 1.0 mm in diameter, one was between 1.0 mm and 1.5 mm in diameter, and two were >2.0 mm in diameter. Of the 14 impacts on the experiment-tray flanges and walls, six were <0.5 mm in diameter (three were photodocumented as they were considered to be of interest), four were between 0.5 mm and 1.0 mm in diameter, and four were between 1.0 mm and 1.5 mm in diameter. On the experiment-tray clamps, 18 of the 21 impacts identified were <0.5 mm in diameter (five of these were photodocumented), two were between 0.5 mm and 1.0 mm in diameter, and one was between 1.0 mm and 1.5 mm in diameter.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	18	6	34	58@
>0.5 mm	3	8	30	41
TOTALS	21	14	64	99@

@ Survey for "Too Smalls" was incomplete.

The largest impact features identified were (1) an ~2.7 mm diameter crater located on the white painted aluminum EPDS cover and which completely penetrated the cover, (2) an ~1.2 mm diameter crater in the experiment-tray flanges, and (3) an ~1.4 mm diameter crater in an experiment-tray clamp. A total of 56 features were photodocumented from tray D08.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 22, 1990 while the experiment tray was mounted on the spacecraft. This inspection identified nine features which might be destroyed by attachment of the experiment-tray cover and two features which would be destroyed by emplacement in the experiment-tray rotator. These latter impact features were estimated to be <0.5 mm in diameter. These latter features were not examined or photodocumented, nor were they included in the numerical summary given above. The Principal Investigator would not allow the cover gasket to be cut to provide protection to any of the impact features with which it would come into contact. One feature each was identified on clamps C01 and C07. Two features were identified on clamp C06; three features each were identified on clamps C02, C03, and C05; four features each were identified on clamps C04 and C08.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations or spallation features on the front or back of the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

The detailed examination and photodocumentation of tray D08 was conducted on February 26 and 27, 1990 in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #3. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	57	959	55	-15
Center	614	958	613	-15
Far Right	1173	958	1169	-16

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC010001.D08	RC010001.D08	92	23		0.3	Al	*k*
LC020001.D08	RC020001.D08	55	30		0.4	Al	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC040001.D08	RC040001.D08	9	102		1.4	Al	
LC040002.D08	RC040002.D08	9	1		0.5	Al	
LC040003.D08	RC040003.D08	26	118		0.7	Al	
LC050001.D08	RC050001.D08	62	34		0.7	Al	
LC050002.D08	RC050002.D08	73	2		0.5	Al	
LC060001.D08	RC060001.D08	1	14		0.5	Al	*1*

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.D08	RE000001.D08	-22	941		1.0	Al	*2*
LE000002.D08	RE000002.D08	-22	941		1.0	Al	*3,w*
LE000026.D08	RE000026.D08	1280	193		0.5	Al	
AE000026.D08	BE000026.D08	1280	193		0.5	Al	
LE000034.D08	RE000034.D08	814	-28		0.5	Al	*15*
LE000038.D08	RE000038.D08	271	-26		0.7	Al	
LE000044.D08	RE000044.D08	43	849		0.3, 0.5	Al	*5,g,w*
LE000045.D08	RE000045.D08	4	748		1.0	Al	*w*
LE000046.D08	RE000046.D08	176	929		1.2	Al	*w*
LE000047.D08	RE000047.D08	203	932		0.5	Al	*w*
LE000048.D08	RE000048.D08	270	886		0.4 x 0.5	Al	*20*
LE000049.D08	RE000049.D08	495	976		0.4	Al	*21,k,w*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000003.D08	RE000003.D08	572	653		0.9, 2.5	Al	*4,5,b*
LE000004.D08	RE000004.D08	657	684		2.3, 5.5	Al	*4,5,6,b*
LE000005.D08	RE000005.D08	719	730		0.4, 1.0	Al	*4,5,b*
LE000006.D08	RE000006.D08	1189	838		0.5, 1.4, 12.0	Al	*4,7,b,w*
LE000007.D08	RE000007.D08	1056	830		0.5, 1.2, 10.0	Al	*4,7,b,w*
LE000008.D08	RE000008.D08	1084	809		1.2, 2.4, 40.0	Al	*4,7,b,w*
LE000009.D08	RE000009.D08	1064	794		0.6, 1.5	Al	*4,5,b,w*
LE000010.D08	RE000010.D08	933	769		0.7, 1.5, 25.0	Al	*4,7,b,w*
LE000011.D08	RE000011.D08	1125	748		0.5, 1.6	Al	*4,5,b,w*
LE000012.D08	RE000012.D08	1216	763		0.7, 1.6	Al	*4,5,8,b,w*
LE000013.D08	RE000013.D08	971	653		0.6, 1.5, 18.0	Al	*4,7,b*
LE000014.D08	RE000014.D08	1049	647		0.5, 1.4, 13.0	Al	*4,7,b*
LE000015.D08	RE000015.D08	1204	603		0.5, 1.8, 8.0	Al	*4,7,b*
LE000016.D08	RE000016.D08	903	572		0.8, 2.0, 18.0	Al	*4,7,9,b*
LE000017.D08	RE000017.D08	894	570		0.7, 1.8, 12.0	Al	*4,7,9,b*
LE000018.D08	RE000018.D08	988	455		1.2, 2.2, 25.0	Al	*4,7,10,b*
LE000019.D08	RE000019.D08	1169	345		0.7, 2.4, 8.0	Al	*4,7,8,10,b*
LE000020.D08	RE000020.D08	953	268		0.6, 1.7, 12.0	Al	*4,7,10,b*
LE000021.D08	RE000021.D08	886	218		0.6, 1.7, 14.0	Al	*4,7,10,b*
LE000022.D08	RE000022.D08	393	315		0.5	Al	
LE000023.D08	RE000023.D08	512	311		0.7	Al	
LE000024.D08	RE000024.D08	776	311		1.1	GrEp	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000025.D08	RE000025.D08	973	149		0.6, 1.3, 9.0	Al	*4,7,11,b*
LE000027.D08	RE000027.D08	859	112		0.6,1.1,2.0,16.0	Al	*4,12,b*
LE000028.D08	RE000028.D08	897	48		0.9, 1.8, 20.0	Al	*4,7,b*
LE000029.D08	RE000029.D08	961	3		0.5, 1.2	Al	*4,5,b*
LE000030.D08	RE000030.D08	1118	122		2.7, 5.5, 12.0	Al	*4,7,13,b*
LE000031.D08	RE000031.D08	1169	118		0.5, 1.4, 8.0	Al	*4,7,b*
LE000032.D08	RE000032.D08	1192	116		0.6, 1.7, 11.0	Al	*4,7,14,b*
LE000033.D08	RE000033.D08	1246	93		0.5, 2.2	Al	*4,5,10,14,b*
LE000035.D08	RE000035.D08	764	128		0.9	Al	
LE000036.D08	RE000036.D08	506	64		1.5	GrEp	*16*
LE000037.D08	RE000037.D08	504	108		0.5, 3.8	GrEp	*17,b,c*
LE000039.D08	RE000039.D08	266	144		0.6	Al	
LE000040.D08	RE000040.D08	218	169		0.5	Al	*18*
LE000041.D08	RE000041.D08	232	105		0.5 x 0.6	Al	
LE000042.D08	RE000042.D08	133	109		0.7	Al	
LE000043.D08	RE000043.D08	201	45		0.6	Al	*19*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

GrEp - Graphite epoxy composite sample

1 - Wrong coordinates (X = 14, Y = 1) input into image file.
2 - Image taken at ~50° to right of normal to crater.
3 - Same feature as feature #1.
4 - Diameter after comma is diameter of spall zone.
5 - Impact into white painted aluminum.
6 - Impact may have penetrated aluminum cover; crater appeared much deeper than its diameter.
7 - Diameter after first comma is diameter of spall zone; diameter after second comma is diameter of outer ring within which paint is "puffed" up.
8 - Front surface spall in paint is incomplete around crater.
9 - Outer rings of features #16 and #17 overlap each other.
10 - Irregularly shaped spall zone.
11 - Wrong Y-coordinate (Y = 179) input into image file.
12 - Impact feature has two spall zones in layers of paint; diameter after first comma is diameter of inner spall zone, diameter after second comma is diameter of outer spall zone, diameter after third comma is diameter of outer "puff" ring.
13 - Impact completely penetrated the EPDS aluminum cover.
14 - Red material (possibly oxidation) visible around crater rim.
15 - Wrong Y-coordinate (Y = 28) input into image file.
16 - Penetration through several of the composite layers; irregularly shaped crater.
17 - Impact into composite caused front surface spall of material around crater, and some fibers pulled away from impact area.
18 - Wrong coordinates (X = 232, Y = 105) input into image file.
19 - Crater lip broken.
20 - Image taken at 43° below normal to crater.
21 - Irregularly shaped crater.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-193/8
On-Orbit - S32-76-13
Pre-Deintegration - KSC-390C-1031.03, KSC-390C-1031.05, KSC-390C-1031.09
Post Deintegration - KSC-390C-1534.05
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - D08C01, D08C04, D08C05
Clamp Bolts - D08S06A

ACCOMPANYING FIGURES:

Figure D08-1. This post-deintegration view shows the front of the entire D08 experiment tray. The active canister is located on the left.

LDEF LOCATION:	**D09**
TRAY IDENTIFICATION:	**M0003**
EXPERIMENT TITLE:	**SPACE ENVIRONMENT EFFECTS ON SPACECRAFT MATERIALS**
PRINCIPAL INVESTIGATOR:	**M. MESHISHNEK** **THE AEROSPACE CORPORATION** **EL SEGUNDO, CALIFORNIA**
	M0002-1 **TRAPPED PROTON ENERGY SPECTRUM DETERMINATION** **R. REDUS** **SPACE PHYSICS DIVISION** **AIR FORCE GEOPHYSICS LABORATORY** **HANSCOM AIR FORCE BASE** **MASSACHUSETTS**

SUMMARY OF OBSERVATIONS

Bay D09 contained a 3"-deep (7.6 cm), integrated, passive experiment tray which housed two experiments: M0003 designed to study space exposure effects on spacecraft materials, and M0002-1 designed to study ion fluxes with energies greater than 1 MeV.

The M0003 experiment was designed to study the changes in the properties and structure of materials after exposure to the space environment and to compare these changes with predictions based on laboratory experiments. The M0003 experiment occupied 75 percent of this 3"-deep (7.6 cm) peripheral tray. The M0003 experiment consists of 19 subexperiments involving a number of DOD laboratories and contractor organizations. The hardware consists of four peripheral trays (D03, D04, D08, and D09), two experiment power and data systems (EPDS), two experiment exposure control canisters (EECC), and LiO_2 batteries to satisfy power requirements. Tray D09 contained a variety of thermal control coatings, composites, laser optics electronic piece parts, fiber optics, and solar cells.

The M0002-1 experiment was designed to measure the flux and energy spectrum of protons with energies of 1 to 10 MeV. The M0002-1 tray is a passive experiment which occupied 25 percent of this 3"-deep (7.6 cm) peripheral tray. The experiment consists of six stacks of passive plastic detectors (CR-39) arranged in portions of three LDEF trays located in Bays D09, D03, and G12. The stacks are 1.49" (3.8 cm) square and 2.60" (6.6 cm) high. They are mounted in containers arranged in the trays to be normal to the Earth's magnetic field in the South Atlantic. The bottom half of each stack is composed of CR-39 without DOP and is 0.022" (0.56 mm) thick. The next 40 percent of the stack is CR-39 with DOP and is 0.022" (0.56 mm) thick. The top 10 percent of the stack is CR-39 with CHCP and is 0.011" (0.28 mm) thick. The top layer of plastic is directly exposed to space. A sheet of aluminum 0.001" (25 μm) thick separates each layer of plastic.

The M&D SIG survey identified a total of 140 features on the D09 experiment tray including the experiment-tray bolts, clamps, shims, and flanges. Of the 140 impacts found, 93 features did not meet the 0.5 mm diameter criteria for impact craters or the 0.3 mm diameter criteria for penetrations. Nineteen of these features were located on the experiment-tray clamps and bolts (of which two features were imaged), two were located on the tray flanges, and the remaining 72 were located on the experiment-tray surface. Of the remaining 47 imaged features, five were located on the experiment-tray flanges and ranged in diameter from 0.5 mm to 1.2 mm. The 42 remaining impacts were located on the experimental surfaces of M0003 and M0002-1. Thirty-six of these

impacts were located on experiment M0003 and ranged in diameter from 0.5 mm to 1.8 mm, with seven features being penetrations which ranged in diameter from 0.4 mm to 0.8 mm. Six of these impacts were located on experiment M0002-1 and ranged in diameter from 0.5 mm to 2.1 mm, with one penetration with a diameter of ~1.1 mm. The M&D SIG A-Team did not complete the survey for "Too Smalls". The M0002-1 experiment was deintegrated by the Principal Investigator and provided to the M&D SIG for additional documentation. The deintegrated experiment was assigned the component designation "E01".

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm				@
>0.3 mm			7	7
<0.5 mm	19	2	72	93@
>0.5 mm		5	35	40
TOTALS	19	7	114	140@

@ Survey for "Too Smalls" was incomplete.

The largest impact features identified on tray D09 were (1) a circular impact ~1.2 mm located on the experiment-tray flange, (2) a circular impact ~1.8 mm in diameter located on the M0003 experimental surface, and (3) a circular impact ~2.1 mm in diameter located on the M0002-1 experimental surface.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment tray was mounted on the spacecraft. The M&D SIG identified nine features which might be damaged by the attachment of the experiment-tray cover and six additional features which could be damaged or destroyed by placing the experiment tray within the experiment-tray rotator stand. These latter features were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in three locations to prevent it from coming into contact with the features and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There was one impact on the experiment-tray flange which caused a bulge through the back of the 0.0625" (1.6 mm) thick flange. This impact feature was documented with the M&D SIG microscopes and also with 35-mm photos to show the spray patterns around the impact.

DOCUMENTATION:

On February 27, 1990 the M0003 and M0002-1 experiment tray was inspected and photodocumented in the vertical position using M&D SIG system #1 and impact coordinates were determined using Coordinate Registration System #1. There were instances, because the tray was so damaged, when a metric tape measure had to be used to define coordinates in the lower left portion of the tray. The deintegrated M0002-1 experiment was photodocumented in the horizontal position by M&D SIG System #2 on February 28, 1990, and coordinates were determined using a metric tape measure due to the awkwardness of the experimental surface. The detailed inspection of the clamps and bolts was performed on February 26, 1990, on M&D SIG System #3 and impact coordinates were determined using a small metric scale.

Bolt-Hole Registration (mm)

	TOP X	TOP Y	BOTTOM X	BOTTOM Y
Far Left	•	•	63	-15
Center	•	•	621	-15
Far Right	•	•	1179	-15

• - Bolt-holes obstructed.

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC030001.D09	RC030001.D09	62	49		0.5	Al	
LC040001.D09	RC040001.D09	10	1		0.5	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.D09	RE000001.D09	1285	670		0.5	Al	
AE000001.D09	BE000001.D09	1285	670		1.2	Al	*3*
LE000005.D09	RE000005.D09	137	954		1.2	Al	
LE000012.D09	RE000012.D09	877	971		0.9	Al	
LE000029.D09	RE000029.D09	656	-4		0.8	Al	
LE000030.D09	RE000030.D09	1220	-18		1.2	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000002.D09	RE000002.D09	225	871		6.0	ND	*1,4*
LE000003.D09	RE000003.D09	380	888		6.6	ND	*1,4*
LE000004.D09	RE000004.D09	320	960		5.2	ND	*1,4*
LE000006.D09	RE000006.D09	465	908		1.4	composite	
LE000007.D09	RE000007.D09	520	906		0.2	glass	*1,5*
LE000008.D09	RE000008.D09	488	879		0.4	glass	*1,6*
LE000009.D09	RE000009.D09	486	834		0.7	glass	*1,7*
LE000010.D09	RE000010.D09	520	836		0.3	glass	*1,8*
LE000011.D09	RE000011.D09	618	861		0.2	glass	*1,9*
LE000013.D09	RE000013.D09	753	744		0.4	ND	*1,10*
LE000014.D09	RE000014.D09	725	581		0.3	solar cell	*1,11*
LE000015.D09	RE000015.D09	722	599		0.3	solar cell	*1,12*
LE000016.D09	RE000016.D09	801	599		0.5	solar cell	*1,13*
LE000017.D09	RE000017.D09	756	486		1.4	TC	*1,14*
LE000018.D09	RE000018.D09	765	538		0.5	ND	*1*
LE000019.D09	RE000019.D09	832	357		1.8	ND	*1*
LE000020.D09	RE000020.D09	669	456		0.2	glass	*1,15*
LE000021.D09	RE000021.D09	564	264		0.5	thin metal?	*1,16*
LE000022.D09	RE000022.D09	680	201		0.7	ND	*1*
AE000022.D09	BE000022.D09	680	201		0.7	ND	*1,17*
LE000023.D09	RE000023.D09	871	443		0.6	ND	*1,18*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000024.D09	RE000024.D09	1152	436		0.7	sheet metal?	*1,19*
LE000025.D09	RE000025.D09	885	494		0.9	ND	*1*
LE000026.D09	RE000026.D09	655	64		1.2	Al	*1*
LE000027.D09	RE000027.D09	489	82		0.7	Al	*1*
LE000028.D09	RE000028.D09	687	158		0.6	ND	*1*
LE000031.D09	RE000031.D09	202	281		0.4	Al foil	*1,20*
LE000032.D09	RE000032.D09	237	312		0.7	Al foil	*1,21*
LE000033.D09	RE000033.D09	245	315		0.8	ND	*1*
LE000034.D09	RE000034.D09	267	233		0.7	ND	*1*
LE000035.D09	RE000035.D09	191	354		0.5	ND	*1*
LE000036.D09	RE000036.D09	218	30		0.5	ND	*1,22*
LE000037.D09	RE000037.D09	390	116		0.5	ND	*1*
LE000038.D09	RE000038.D09	234	499		0.5	ND	*1*
LE000039.D09	RE000039.D09	237	516		0.8	ND	*1*
LE000040.D09	RE000040.D09	302	464		0.5	ND	*1*
LE000041.D09	RE000041.D09	298	347		0.3	optical surface?	*1*
LE010001.D09	RE010001.D09	216	65		0.8	Al	*2,23*
LE010002.D09	RE010002.D09	339	40		0.5	Al	*2,24*
LE010003.D09	RE010003.D09	25	44		0.6	Al	*2,25,k*
LE010004.D09	RE010004.D09	304	432		1.1	Al	*2,26*
LE010005.D09	RE010005.D09	8	395		0.5	Al	*2,27*
LE010006.D09	RE010006.D09	0	0		ND	detector surface	*2,28,31*
LE010007.D09	RE010007.D09	190	240	15	2.1	Al	*2,29*
LE010008.D09	RE010008.D09	1	1		ND	detector	*2,30,31*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined
TC - Thermal control surface

1 - Features located in experiment M0003.
2 - Features located in experiment M0002-1.
3 - Image taken of backside of tray lip to show dimple made by feature LE000001.D09.
4 - Spray pattern on bumper material - not associated with an impact feature.
5 - Impact into glass substrate, spall zone ~1.7 mm in diameter.
6 - Impact into glass substrate, spall zone ~1.5 mm in diameter, angle of scope 65°.
7 - Impact into glass substrate, spall zone ~1.4 mm in diameter, angle of scope 65°.
8 - Impact into glass substrate, spall zone ~1.0 mm in diameter.
9 - Impact into glass substrate, spall zone ~1.2 mm in diameter, angle of scope 65°.
10 - Possible low velocity impact, double spall zone D_1=~0.8 mm, D_2=~1.2 mm.
11 - Fracture zone D=~0.7 mm.
12 - Fracture zone D=~1.0 mm.
13 - Fracture zone D=~1.7 mm.
14 - Image illuminated with ringlight instead of goosenecks.
15 - Fracture zone D=~1.8 mm.
16 - Penetration in unknown thin metal material.
17 - Reason unknown for second photo.
18 - Image taken with paint chip in view.
19 - Penetration in sheet metal material next to small vent hole.
20 - Darkened zone in aluminum foil, D=~1.4 mm.

21 - Delamination area ~7.0 mm in diameter.
22 - Image taken with 0.4 lower objective lens.
23 - Spall zone diameter is ~2.0 mm.
24 - Potential projectile melt in crater bottom, also crater protection device was placed over impact.
25 - Interesting spall pattern, possible low velocity impact.
26 - Penetration through top layer of painted aluminum surface, spall zone ~2.2 mm in diameter.
27 - Spall zone ~D=1.5 mm, possible low velocity impact.
28 - Image taken of surface of detector #1 at 25X magnification.
29 - Image taken at very high angle because location of crater was on side of detector #2.
30 - Image taken of bottom of detector #1, at low magnification.
31 - Coordinates stored with image are meaningless.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-8/2
On-Orbit - S32-78-093
Pre-deintegration - KSC-390C-1030.08, KSC-390C-1030.12, KSC-390C-1031.02
Post Deintegration - KSC-390C-1529.01
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps -D09C03, D09C04, D09C07, and D09C08
Clamp Bolts - D09S04A

LDEF LOCATION: D10
TRAY IDENTIFICATION: A0054
EXPERIMENT TITLE: SPACE PLASMA HIGH-VOLTAGE DRAINAGE EXPERIMENT
PRINCIPAL INVESTIGATOR: W. L. TAYLOR
TRW SPACE AND TECHNOLOGY GROUP
REDONDO BEACH, CALIFORNIA

SUMMARY OF OBSERVATIONS

The A0054 experiment consisted of two experiment trays D10 and B04 containing large numbers of dielectric samples under electrical stress in space. The samples included encapsulated solar cell samples and thin polymeric films such as Mylar, FEP Teflon, and Kapton/vacuum-deposited aluminum bonded by a conductive epoxy cement to an underlying Kevlar honeycomb support structure. The dielectric films are of various thicknesses, and some are deliberately flawed. Each dielectric sample is equipped with a self-contained battery and power processor unit to furnish an applied bias voltage. The objectives of the A0054 experiment are to study the behavior of electrically stressed dielectric materials in space and to study the effects of the space environment on solar cells, spacecraft materials, and electrical components. Tray D10 occupied a 3"-deep (7.6 cm) peripheral tray on the leading edge of the spacecraft.

The entire outer surface of aluminized Kapton was completely lost due to atomic oxygen erosion, leaving the VDA film covering the dielectrics exposed to the space environment. Only small pieces of Kapton tape were left on the aluminum frames holding the dielectric samples in place. Upon initial visual inspection of the experiment, there appeared to be a lot of impacts into the outer surfaces of the VDA film. However, on closer inspection with the microscope, these impacts turned out to be small tears in the surface. Many features had interesting spall and foil peeling patterns caused by the impacts into the VDA film and the Kapton tape. There were numerous impact features which penetrated the Kapton tape and the VDA film impacting into the aluminum substrate. These impact features possessed a central pit in the aluminum and an outer penetration through the Kapton tape or VDA film. The outer penetrations possessed high raised lips which were generally rolled back, forming a volcano affect. The morphology of the features on the experiment-tray flanges and clamps were all typical of hypervelocity impact craters into aluminum.

The M&D SIG survey identified a total of 399 features on the D10 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as A0054 experimental surfaces. Of the 399 impacts found, 344 features did not meet the 0.5 mm diameter criteria for impact craters or the 0.3 mm diameter criteria for penetrations so these features were not imaged. Out of the 52 features which were imaged ten were classified as penetrations and ranged in diameter from 0.3 mm to 0.7 mm. The remaining 42 imaged features were classified as impact craters and ranged in size from 0.3 mm to 2.5 mm. Thirty-four of the imaged features were located on the tray surface, four were located on the tray flanges, and four were located on tray clamps C02, C03, C07, and C08. In addition, a piece of aluminized Kapton from this experiment was found on LATS, surveyed by the M&D SIG, and three penetrations <0.3 mm in diameter were found and imaged. This aluminized Kapton piece was assigned component designation "E01".

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm				5*
>0.3 mm			10	10
<0.5 mm	31			342*
>0.5 mm	4	4	34	42
TOTALS	35			399*

* The location of the "Too Smalls" was not documented.

The largest impact features identified on tray D10 were (1) an oblique impact ~1.3 mm x 0.9 mm wide located on the surface of the A0054 experiment, (2) a circular impact ~2.5 mm in diameter located in the fiberglass substrate, and (3) a circular impact ~1.1 mm in diameter located on the aluminum divider.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment tray was mounted on the spacecraft. The M&D SIG identified two features which might be damaged by the attachment of the experiment-tray cover and five additional feature which could be damaged or destroyed by placing the experiment tray within the experiment-tray rotator stand. These latter features were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations of the 0.0625" (1.6 mm) thick experiment-tray flanges and no bulges or spalls on the back of the tray flanges. There were strong contamination patterns on the sides of the tray at the corners.

DOCUMENTATION:

On March 12, 1990 the A0054 experiment tray was inspected and photodocumented in the vertical position by M&D SIG system #1 and impact coordinates were determined using Coordinate Registration System #1. The inspection of the aluminized Kapton foil found on LATS was performed on February 21, 1990 using M&D SIG System #2; feature coordinates were determined using a metric scale. The detailed inspection of the clamps and bolts was performed on March 9, 1990, on M&D SIG System #3 and impact coordinates were determined using a small metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	73	956	68	-16
Center	631	960	631	-16
Far Right	1191	959	1184	-15

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC020001.D10	RC020001.D10	5	5		0.6	Al	
LC030001.D10	RC030001.D10	3	24		0.5	Al	
LC070001.D10	RC070001.D10	109	19		0.7	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.D10	RE000001.D10	392	992		0.5	Al	
LE000002.D10	RE000002.D10	813	990		0.7	Al	
LE000048.D10	RE000048.D10	824	-46		0.7	Al	
LE000049.D10	RE000049.D10	759	-17		1.2	Al	*1*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000003.D10	RE000003.D10	201	826		0.5	Al	*k*
LE000004.D10	RE000004.D10	52	758		0.3	Al,Kapton	*2*
LE000005.D10	RE000005.D10	360	739		0.4	Glass/Epoxy	*3*
LE000006.D10	RE000006.D10	244	715		0.2	Al,Kapton	*4*
LE000007.D10	RE000007.D10	393	873		0.6	Glass/Epoxy	*5*
LE000008.D10	RE000008.D10	501	926		0.4	Al,Kapton	*6*
LE000009.D10	RE000009.D10	490	867		0.3	Al,Kapton	*7*
LE000010.D10	RE000010.D10	601	847		0.2	Al,Kapton	*8,9*
LE000011.D10	RE000011.D10	612	765		0.3	Al	*10*
LE000012.D10	RE000012.D10	520	778		0.4	Si	*11,12*
LE000013.D10	RE000013.D10	726	848		0.8	Al	
LE000014.D10	RE000014.D10	1239	889		0.4	Kapton	*6*
LE000015.D10	RE000015.D10	1162	742		0.6	Foil,Kapton	*13*
LE000016.D10	RE000016.D10	1187	748		0.5	Kapton	*6*
LE000017.D10	RE000017.D10	214	652		0.4	Al,Kapton	*6,14*
LE000018.D10	RE000018.D10	234	618		0.9	Al,Kapton	
LE000019.D10	RE000019.D10	181	248		0.5	Al,Kapton	
LE000020.D10	RE000020.D10	240	301		0.5	Foil,Kapton	*13*
LE000021.D10	RE000021.D10	357	385		0.7	Foil	
LE000022.D10	RE000022.D10	544	384		0.4	Foil	*15*
LE000023.D10	RE000023.D10	606	275		0.2	Kapton,FG	*16*
LE000024.D10	RE000024.D10	681	294		0.5	Foil	
LE000025.D10	RE000025.D10	702	407		0.6	Foil	
LE000026.D10	RE000026.D10	767	241		0.3	Al,Kapton	
LE000027.D10	RE000027.D10	753	328		0.7	Foil,FG	*15*
LE000028.D10	RE000028.D10	594	510		1.8	Foil,FG	*15*
LE000029.D10	RE000029.D10	678	566		0.9	Foil	*18,b*
LE000030.D10	RE000030.D10	707	648		0.8	Foil	*18,b*
LE000031.D10	RE000031.D10	759	636		0.2	Foil	*18,19,20,b*
LE000032.D10	RE000032.D10	750	534		0.5	Foil	*21*
LE000033.D10	RE000033.D10	916	531		0.6	Foil	
LE000034.D10	RE000034.D10	978	684		1.3 x 0.9	Foil	*19*
LE000035.D10	RE000035.D10	1198	594		0.5	Foil	*22*
LE000036.D10	RE000036.D10	1163	528		1.0	Foil	
LE000037.D10	RE000037.D10	1113	428		0.8	Al,Kapton	*23*
LE000038.D10	RE000038.D10	983	376		0.7	Foil	
LE000039.D10	RE000039.D10	941	252		0.5	Kapton	
LE000040.D10	RE000040.D10	202	218		0.5	Kapton	
LE000041.D10	RE000041.D10	194	41		0.7	Kapton	
LE000042.D10	RE000042.D10	293	208		0.5	Foil	*18,b*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000043.D10	RE000043.D10	269	105		1.0	Foil	
LE000044.D10	RE000044.D10	288	98		0.6	Foil	*k,7*
LE000045.D10	RE000045.D10	598	238		2.5	Al,Kapton	
LE000046.D10	RE000046.D10	1074	222		1.1	Kapton	
LE000047.D10	RE000047.D10	1057	205		0.2	Al,Kapton	*24*
LE010001.D10	RE010001.D10	4	11		0.2	Kapton	*6,18,b*
LE010002.D10	RE010002.D10	14	10		0.1	Kapton	*6,18,b*
LE010003.D10	RE010003.D10	12	83		0.2	Kapton	*6,25,k*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Kapton tape on tray lip.
2 - Outer penetration diameter D=~0.6 mm.
3 - Crater looks like quartz glass.
4 - Impact penetrated Kapton tape. Outer penetration diameters D_1=~0.7 mm, D_2=~1.2mm.
5 - Image taken at a 45° angle to the crater.
6 - Penetration through Kapton tape.
7 - Possible oblique impact.
8 - Outer penetration diameter D=~0.9 mm.
9 - Wrong coordinates (X = 612, Y = 765) input with image file.
10 - High raised lip, secondary impact at 5:00 position.
11 - Wrong coordinates (X = 0, Y = 0) input with image file.
12 - Outer penetration into the cover glass D=~1.1 mm. Various cracks, wires ruptured above and below crater.
13 - Impact into foil with rough Kapton on surface.
14 - Outer penetration diameter D=~0.7 mm with very high raised lip.
15 - Impact into the foil through the fiberglass.
16 - Impact through Kapton layers into fiberglass. Outer penetration diameters D_1=~0.5 mm, D_2=~0.8 mm.
17 - Outer penetration diameter D=~0.6 mm.
18 - Big spall zone.
19 - Diamond shaped spall zone.
20 - Outer penetration diameter D=~0.3 mm.
21 - Wrong coordinates (X = 916, Y = 531) input with image file.
22 - Aluminized mylar peeled back.
23 - Outer penetration diameter D=~2.0 mm.
24 - Outer penetration diameters D_1=~0.4 mm, D_2=~0.5 mm.
25 - Top layer is torn around penetration; apparent ejecta material contained in second layer.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-193/7
On-Orbit - S32-76-38
Pre-deintegration - KSC-390C-1028.12, KSC-390C-1029.02, KSC-390C-1029.07
Post Deintegration - KSC-390C-1770.04
M&D SIG Photos - None

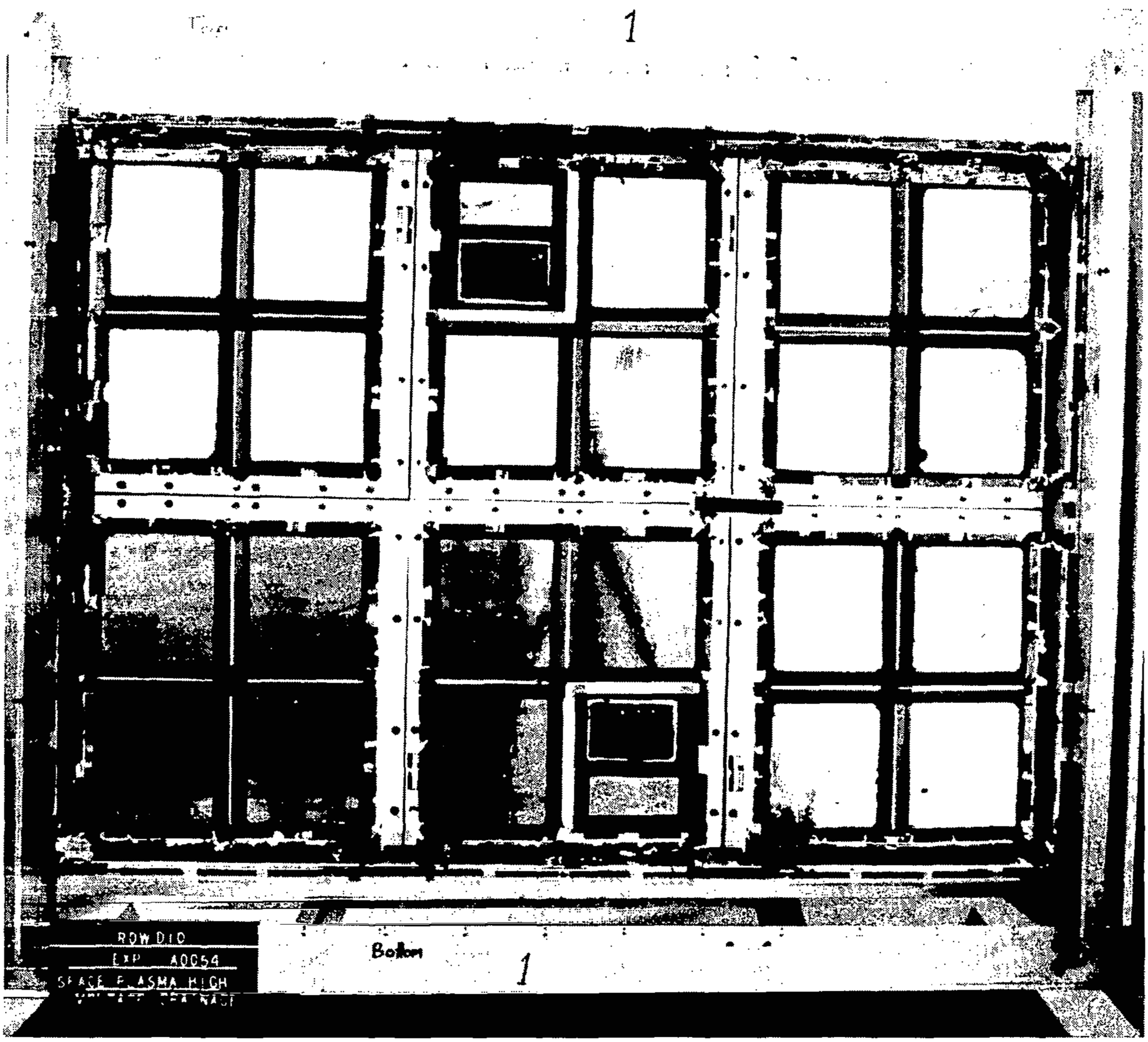
ARCHIVED MATERIALS:

Clamps - D10C02, D10C03, D10C07, and D10C08
Clamp Bolts - D10S03C, D10S05B

Other - LD-22 (D10E01, 1 and D10E01, 2)
LD-17 (D10E01, 3 Layer 1)
LD-18 (D10E01, 3 Layer 2)

ACCOMPANYING FIGURES:

Figure D10-1. This post-deintegration view shows the front of the entire D10 experiment tray.



LDEF LOCATION: D11
EXPERIMENT IDENTIFICATION: A0178
EXPERIMENT TITLE: A HIGH-RESOLUTION STUDY OF ULTRA-HEAVY COSMIC-RAY NUCLEI
PRINCIPAL INVESTIGATOR: D. O'SULLIVAN
DUBLIN INSTITUTE FOR ADVANCED STUDIES
DUBLIN, IRELAND

SUMMARY OF OBSERVATIONS

Bay D11 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46"-long (116.8 cm), 10" (25.4 cm) diameter aluminum cylinders which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with a ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (facing space) of FEP Teflon (~120 μm thick) backed with a thin layer of silver-inconel (~200 to 300 Å thick), which in turn is backed by Chemglaze Z306 black conductive paint and binding medium (~80 to 100 μm thick). The structure and attachments for the experiment tray consisted of the tray flanges and walls (0.125" [3.2 mm] thick chromic anodized 6061-T6 aluminum), the experiment-tray clamps (0.19" [4.8 mm] thick chromic anodized 6061-T6 aluminum), and the experiment-tray clamp bolts (303 stainless steel). The backs of the trays were also covered with a reflective thermal blanket.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted Teflon material. Commonly, the Teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. When impacts occurred into the velcro which supported the thermal blanket materials, large delamination areas were very common around the penetration. Many penetrations possessed several sharp, distinct, colored rings, while others exhibited a more continuous halo phenomenon where the change from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impacts into aluminum.

The M&D SIG survey identified a total of 437 features on the D11 experiment tray including the experiment-tray clamps and flanges, as well as the thermal insulation blanket. Of these, 379 were found on the thermal blanket, all but a few representing penetrations through the blanket. Three hundred and twenty features from the blanket were below the 0.3 mm diameter photodocumentation threshold, 58 features were between 0.3 mm and 1.0 mm in diameter, and one feature was photodocumented which was between 1.0 mm and 1.5 mm in diameter. Thirty two features were found on the tray flanges, 23 of which were <0.5 mm in diameter, six of which were between 0.5 mm and 1.0 mm in diameter, two of which were between 1.0 mm and 1.5 mm in diameter, and the final one was an ejecta spray pattern. The remaining 26 features were located while scanning the associated bolts, clamps and shims for tray D11. Twenty one features on the clamps (C01-C08)

were <0.5 mm in diameter, and the remaining five were between 0.5 mm and 1.0 mm in diameter located on clamps C02, C03, and C05.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			320	320
>0.3 mm			59	59
<0.5 mm	21	23		44
>0.5 mm	5	9		14
TOTALS	26	32	379	437

The largest impact feature documented on this tray was on the aluminum experiment-tray flange and measured ~6.8 mm x 2.4 mm (LE000025.D11). This oblique impact feature included a large ejecta spray pattern and bulged the back surface of the experiment-tray flange. An ~1.3 mm diameter penetration hole was found in the thermal blanket. In one unusual instance (LE000062.D11), a non-penetrating blanket impact feature is accompanied by a large (4.4 mm diameter) ring, extended fracture zone (1.3 mm diameter) and spray ejecta. There was also a notable impact feature on the head of clamp bolt S01A.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection (February 21, 1990) was conducted while the experiment tray was mounted on the spacecraft and identified one feature which might be damaged by the attachment of the experiment-tray cover and no features which could be damaged or destroyed by placing the experiment tray within the experiment-tray rotator stand. In an effort to protect the interesting feature within the experiment-tray cover area, the cover gasket was cut in one location to prevent it from coming into contact with this feature and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There was one noticeable bulge on the 0.125" (3.2 mm) thick experiment-tray flanges. This was located behind the large impact on the right flange (LE000025.D11).

DOCUMENTATION:

Examination and photodocumentation of tray D11 was conducted on March 21, 1990 in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #3. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on these materials were measured with a small metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	60	948	57	-28
Middle	618	948	616	-28
Far Right	1176	948	1174	-29

Fiducial Mark Locations (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Left	194	910	246	26
Middle	624	903	564	25
Right	1005	902	1030	25

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC020001.D11	RC020001.D11	91	14		0.5	Al	
LC020002.D11	RC020002.D11	112	11		0.5	Al	
LC020003.D11	RC020003.D11	127	38		0.7	Al	
LC030001.D11	RC030001.D11	45	3		0.9	Al	
LC050001.D11	RC050001.D11	92	21		0.6	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000024.D11	RE000024.D11	1276	639		0.6	Al	*2*
LE000025.D11	RE000025.D11	1254	724		2.4 x 6.8	Al	*d,h*
LE000026.D11	RE000026.D11	-17	835		0.5	Al	
LE000028.D11	RE000028.D11	192	936		0.7	Al	
LE000032.D11	RE000032.D11	622	928		0.7	Al	
LE000035.D11	RE000035.D11	744	929		1.0	Al	
LE000041.D11	RE000041.D11	1081	974		1.1	Al	
LE000053.D11	RE000053.D11	522	-32		0.7	Al	
LE000058.D11	RE000058.D11	691	-9		0.5	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.D11	RE000001.D11	18	523		0.2 x 0.3	TB	*RD=2.4 mm*
LE000002.D11	RE000002.D11	53	685		0.3	TB	*RD=3.8 mm*
LE000003.D11	RE000003.D11	109	641		0.4 x 0.5	TB	*RD=1.5 mm*
LE000004.D11	RE000004.D11	42	483		0.3	TB	*RD=2.8 mm*
LE000005.D11	RE000005.D11	157	463		0.4 x 0.6	TB	*RD=3.0 mm*
LE000006.D11	RE000006.D11	251	463		0.3	TB	*RD=4.8 mm*
LE000007.D11	RE000007.D11	318	672		0.4	TB	*RD=2.4 mm*
LE000008.D11	RE000008.D11	589	542		0.4	TB	*RD=1.0 mm*
LE000009.D11	RE000009.D11	503	548		0.3	TB	*RD=1.2 mm*
LE000010.D11	RE000010.D11	645	296		0.5 x 0.6	TB	*RD=4.7 mm*
LE000011.D11	RE000011.D11	712	501		0.4	TB	*RD=2.6 mm*
LE000012.D11	RE000012.D11	733	573		0.7	TB	*RD=6.0 mm*
LE000013.D11	RE000013.D11	682	556		0.4 x 0.5	TB	*RD=2.4 mm*
LE000014.D11	RE000014.D11	797	513		0.7	TB	*RD=7.0 mm*
LE000015.D11	RE000015.D11	817	508		0.3	TB	*RD=5.0 mm*
LE000016.D11	RE000016.D11	1002	460		0.5	TB	*RD=6.0 mm*
LE000017.D11	RE000017.D11	917	496		0.4	TB	*RD=2.0 mm*
LE000018.D11	RE000018.D11	902	544		0.5 x 0.6	TB	*RD=7.3 mm*
LE000019.D11	RE000019.D11	922	555		0.4	TB	*RD=5.5 mm*
LE000020.D11	RE000020.D11	1073	635		0.4	TB	*RD=5.6 mm*
LE000021.D11	RE000021.D11	1093	629		0.3	TB	*RD=5.0 mm*
LE000022.D11	RE000022.D11	1125	628		0.3	TB	*RD=5.2 mm*
LE000023.D11	RE000023.D11	1210	632		0.8	TB	*1,RD=13 mm*
LE000027.D11	RE000027.D11	18	815		0.3	TB	*RD=1.4 mm*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000029.D11	RE000029.D11	305	740		0.2 x 0.3	TB	*RD=4.3 mm*
LE000030.D11	RE000030.D11	463	811		0.6 x 0.8	TB	*RD=6.5 mm*
LE000031.D11	RE000031.D11	504	786		0.3	TB	*RD=4.5 mm*
LE000033.D11	RE000033.D11	675	866		0.5	TB	*RD=3.3 mm*
LE000034.D11	RE000034.D11	751	864		0.5	TB	*RD=2.8 mm*
LE000036.D11	RE000036.D11	766	716		0.3	TB	*RD=3.3 mm*
LE000037.D11	RE000037.D11	878	753		0.5	TB	*RD=3.3 mm*
LE000038.D11	RE000038.D11	917	817		0.4	TB	*RD=2.7 mm*
LE000039.D11	RE000039.D11	1018	746		0.5	TB	*RD=5.7 mm*
LE000040.D11	RE000040.D11	1054	817		0.3	TB	*RD=4.0 mm*
LE000042.D11	RE000042.D11	1109	844		0.4	TB	*RD=2.1 mm*
LE000043.D11	RE000043.D11	1150	853		0.3	TB	*RD=1.5 mm*
LE000044.D11	RE000044.D11	629	841		0.3	TB	*RD=4.7 mm*
LE000045.D11	RE000045.D11	21	293		0.6	TB	*RD=7.5 mm*
LE000046.D11	RE000046.D11	73	280		0.3	TB	*RD=4.7 mm*
LE000047.D11	RE000047.D11	182	213		0.4 x 0.6	TB	*RD=7.4 mm*
LE000048.D11	RE000048.D11	157	180		0.3	TB	*RD=4.6 mm*
LE000049.D11	RE000049.D11	226	37		0.7	TB	*RD=8.5 mm*
LE000050.D11	RE000050.D11	374	107		0.3	TB	*RD=4.4 mm*
LE000051.D11	RE000051.D11	430	240		0.6	TB	*RD=2.5 mm*
LE000052.D11	RE000052.D11	582	116		0.3	TB	*RD=3.7 mm*
LE000054.D11	RE000054.D11	616	16		0.4	TB	*RD=3.2 mm*
LE000055.D11	RE000055.D11	645	295		0.6	TB	*RD=4.5 mm*
LE000056.D11	RE000056.D11	626	138		0.4	TB	*RD=1.0 mm*
LE000057.D11	RE000057.D11	668	169		0.6	TB	*RD=2.8 mm*
LE000059.D11	RE000059.D11	728	268		0.3	TB	*RD=5.0 mm*
LE000060.D11	RE000060.D11	786	84		0.3	TB	*RD=4.8 mm*
LE000061.D11	RE000061.D11	918	229		0.5	TB	*RD=1.8 mm*
LE000062.D11	RE000062.D11	963	52		1.3	TB	*3,d,RD=4.2*
LE000063.D11	RE000063.D11	969	237		0.3	TB	*RD=1.2 mm*
AE000063.D11	BE000063.D11	969	237		0.3	TB	*RD=1.2 mm*
LE000064.D11	RE000064.D11	969	240		0.4	TB	*RD=1.2 mm*
LE000065.D11	RE000065.D11	991	137		0.3	TB	*RD=1.1 mm*
LE000066.D11	RE000066.D11	1126	172		0.4	TB	*RD=5.3 mm*
LE000067.D11	RE000067.D11	1143	181		0.8	TB	*RD=7.0 mm*
LE000068.D11	RE000068.D11	1208	236		0.5	TB	*RD=1.9 mm*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

TB - Thermal Blanket (Teflon, silver-inconel, binder, and paint)
RD - Ring feature diameter

1 - Impact removed material from the back of the blanket, ejecta onto black cannister below.
2 - Image taken at 40° from normal to crater.
3 - No penetration, cracks present about impact crater.

OTHER PHOTODOCUMENTATION:

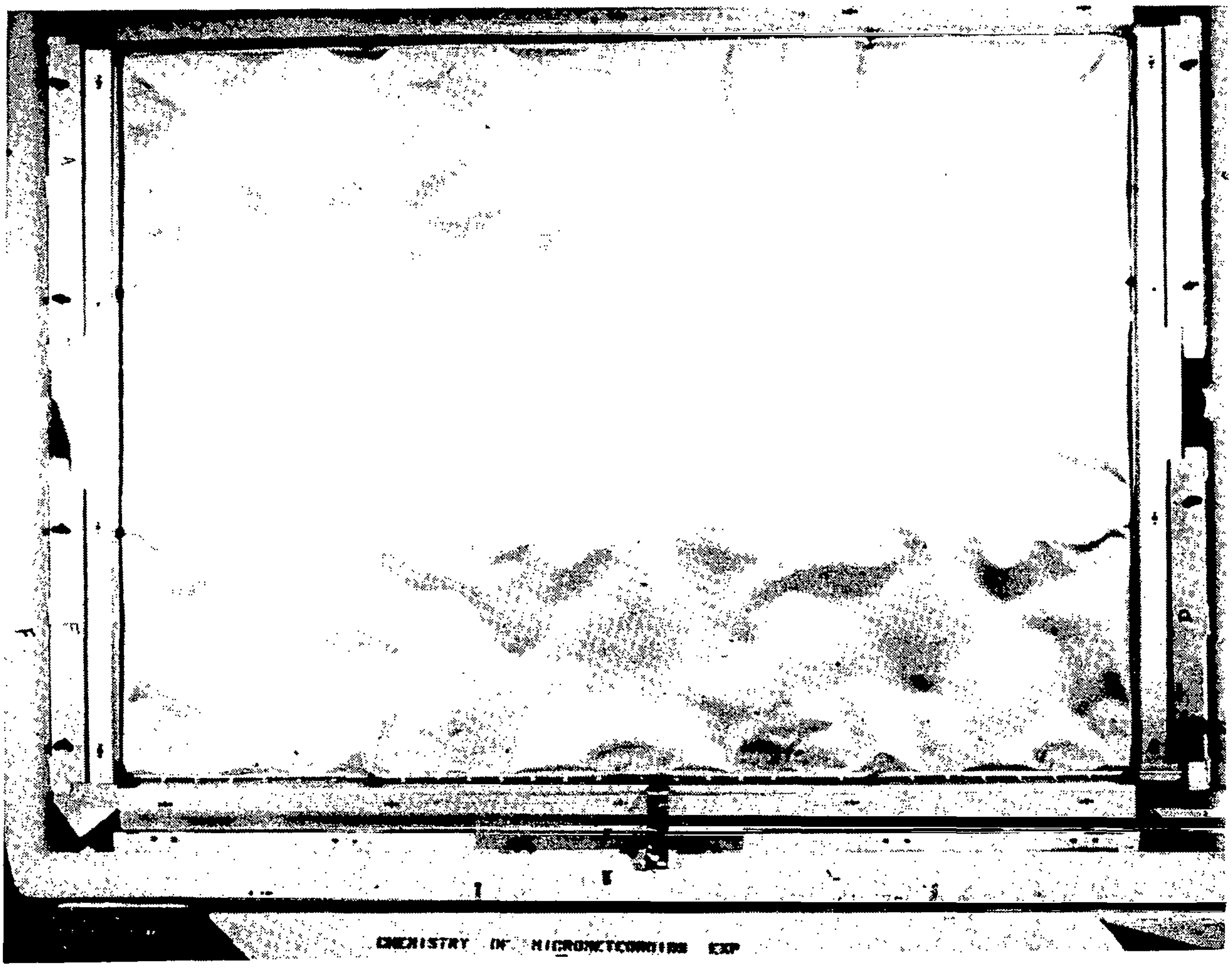
Pre-Flight - 108-KSC-348C-331/9
On-Orbit - S32-78-47
Pre-Deintegration - KSC-390C-1028.09, KSC-390C-1028.11, KSC-390C-1028.05
Post Deintegration - KSC-390C-1768.06
M&D SIG Photos - S90-43482 through S90-43488

ARCHIVED MATERIALS:

Clamps - D11C02, D11C03, D11C04, and D11C05
Clamp Bolt - D11S01A
Thermal Blanket - (D11E00A) - The U.S. third (minus the Materials SIG specimen) resides at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds (minus the Materials SIG grounding-strap specimen) are being archived at ESTEC in The Netherlands. Each blanket third was marked with two small crosses (see Fiducial Mark table below) for indexing and reconstruction purposes.

ACCOMPANYING FIGURES:

Figure D11-1. This post-deintegration view shows the front of the entire D11 experiment thermal blanket. Some impact features are apparent.



LDEF LOCATION: D12
TRAY IDENTIFICATION: A0023
EXPERIMENT TITLE: MULTIPLE-FOIL MICROABRASION PACKAGE
PRINCIPAL INVESTIGATOR: J.A.M. McDONNELL
UNIT FOR SPACE SCIENCES
UNIVERSITY OF KENT
CANTERBURY, UNITED KINGDOM CT28EF

A0180
THE EFFECT OF SPACE ENVIRONMENT EXPOSURE ON THE PROPERTIES OF POLYMER MATRIX COMPOSITE MATERIALS
R.C. TENNYSON
INSTITUTE FOR AEROSPACE STUDIES
UNIVERSITY OF TORONTO
DOWNSVIEW, ONTARIO, CANADA

A0019
INFLUENCE OF EXTENDED EXPOSURE IN SPACE ON MECHANICAL PROPERTIES OF HIGH-TOUGHNESS GRAPHITE-EPOXY COMPOSITE MATERIAL
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ANN ARBOR, MICHIGAN 48109-2125

SUMMARY OF OBSERVATIONS

Bay D12 contained a 3"-deep (7.6 cm), integrated, passive experiment tray which housed one meteoroid/debris-type experiment (A0023), and two experiments (A0180 and A0019) designed to study the effects of extended space exposure on composite materials.

The A0023 experiment was designed to measure the density (flux), size, velocity, radial distribution, and composition of micro-particles in near-Earth space. The detectors exposed rolled aluminum foils as thin as 1.5 μm which were bonded to etched aluminum grids to support the foils and provide a rugged structure. The experiment was located in one-third sections of four trays (C03, E06, C09, and D12) spaced at 90° intervals around the periphery of the spacecraft, as well as in two-thirds of one 3"-deep (7.6 cm) space-facing tray (H11).

The A0180 experiment was designed to measure the effect of various lengths of exposure to a space environment on the mechanical properties, (*i.e.*, strength parameters, coefficients of thermal expansion, impact resistance, crack propagation, and fracture toughness) of selected commercial polymer matrix composite materials. The experiment was divided into three sections, each section consisting of a layered arrangement of both tubular and flat specimens. The tubular specimens are thin walled (0.02" to 0.06" [0.5 to

1.5 mm]) and approximately 1.75" (4.4 cm) in diameter and 4" (10.2 cm) long composite samples of resin-impregnated graphite, boron, S-glass, and (Kevlar) PRD-49 fibers. The flat specimens are of similar thickness and measure 2" (5.1 cm) wide and 5" (12.7 cm) long with composite samples mounted on an uncoated 3/16" (4.8 mm) thick aluminum plate. Aluminum end fittings are bonded to each of the test specimens. The A0180 experiment was divided into three sections, and occupied one-half of the 3"-deep (7.6 cm) peripheral tray.

The A0019 experiment was designed to measure the effects of extended exposure to a space environment on the mechanical properties, (*i.e.*, fracture toughness, tensile strength, and elastic modulus) of a specially toughened T300/5208 graphite-epoxy composite material made from intermittent interlaminar bonding techniques. The 15 passive experiment specimens were mounted on a clad aluminum 0.056" (1.4 mm) thick mounting plate with their flat sides normal to the LDEF radius and occupying 1/6 of the 3"-deep (7.6 cm) peripheral tray.

Impact features residing in the various aluminum hardware associated with each of the four experiments on D12 were typical of hypervelocity impacts into aluminum produced under laboratory conditions. Penetrations through the aluminum foils of A0023 varied from circular to elongate in shape; several penetrations resembled tears and may not have resulted from the penetration of a hypervelocity particle. Impacts into the composite materials of both experiments (A0019 and A0180) were difficult to see due to the darkness and texture of the material. When impact features were found, distinguishable craters or penetration diameters were difficult to determine.

The M&D SIG survey identified a total of 215 features on the D12 experiment tray including the experiment-tray bolts, clamps, shims, and flanges. Of the 215 impacts found, 185 features did not meet the 0.5 mm diameter criteria for impact craters so these features were not imaged. Seventeen of these features were located on the experiment-tray clamps and bolts, 50 were located on the experiment-tray flanges, and 118 were located on the three experimental surfaces. Of the remaining 30 imaged features, four were located on the experiment-tray flanges and ranged in diameter from 0.6 mm to 1.6 mm and one was located on experiment-tray clamp C01. The 25 remaining impacts were located on the three experimental surfaces; ten of which were located on experiment A0023 and ranged in diameter from 0.5 mm to 0.9 mm, four being penetrations which ranged in diameter from 0.3 to 0.8 mm, 11 were located on experiment A0180 and ranged in diameter from 0.4 mm to 0.7 mm, and the remaining four were located on experiment A0019 and ranged in diameter from 0.2 mm to 0.8 mm. The A0023 Principal Investigator later deintegrated a portion of his experiment so the M&D SIG could photodocument an ejecta spray pattern caused by feature LE000026.D12. This component was assigned the designation "E01".

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm				
>0.3 mm			4	4
<0.5 mm	17	50	118	185
>0.5 mm	1	4	21	26
TOTALS	18	54	143	215

The largest impact features identified on tray D12 were (1) a circular impact ~1.6 mm located on the experimental-tray flange, and (2) a circular impact ~0.9 mm in diameter located on the aluminum frame from experiment A0023.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment tray was mounted on the spacecraft. The M&D SIG identified two features which might be damaged by the attachment of the

experiment-tray cover and two additional features which could be damaged or destroyed by placing the experiment tray within the experiment-tray rotator stand. In an effort to protect the most interesting feature within the experiment-tray cover area, the cover gasket was cut in one location to prevent it from coming into contact with the feature and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations of the 0.0625" (1.6 mm) thick experiment-tray flanges and no bulges or spalls on the back of the tray flanges.

DOCUMENTATION:

On March 15, 1990 the experiment tray was inspected and photodocumented in the vertical position using M&D SIG system #1 and impact coordinates were determined using Coordinate Registration System #1. The detailed inspection of the clamps and bolts was also performed on March 15, 1990, on M&D SIG System #3 and impact coordinates were determined using a small metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC010001.D12	RC010001.D12	16	49		0.6	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000018.D12	RE000018.D12	1274	763		0.6	Al	
LE000027.D12	RE000027.D12	353	-20		0.9	Al	
LE000028.D12	RE000028.D12	0	278	35	0.7	Al	*5,f*
LE000029.D12	RE000029.D12	121	0	30	1.6	Al	*f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.D12	RE000001.D12	673	924		0.7	Al	*3*
LE000002.D12	RE000002.D12	1220	783		0.7	Al	*4*
LE000003.D12	RE000003.D12	948	927		0.8	Al	*4*
LE000004.D12	RE000004.D12	1123	685		0.5	Al	*4*
LE000005.D12	RE000005.D12	1020	652		0.2	Graphite	*4,6*
LE000006.D12	RE000006.D12	430	693		0.6	Al	*3*
LE000007.D12	RE000007.D12	637	651		0.7	Graphite	*3*
LE000008.D12	RE000008.D12	570	527		0.5	Al	*3*
LE000009.D12	RE000009.D12	690	540		0.7	Al	*3*
LE000010.D12	RE000010.D12	723	525		ND	ND	*3,7*
LE000011.D12	RE000011.D12	800	345		0.7	ND	*3,8*
LE000012.D12	RE000012.D12	690	417		0.7	Al	*3*
LE000013.D12	RE000013.D12	203	462		0.7	Al	*1,2*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000014.D12	RE000014.D12	380	476		0.5	Al	*1,2*
LE000015.D12	RE000015.D12	220	702		0.6	Al	*1,2*
LE000016.D12	RE000016.D12	370	750		0.4 x 0.5	Al foil	*2*
LE000017.D12	RE000017.D12	370	750		0.3	Al foil	*2*
LE000019.D12	RE000019.D12	451	449		0.6	ND	*3,9,10*
AE000019.D12	BE000019.D12	451	449		0.6	ND	*3,9*
LE000020.D12	RE000020.D12	1220	58		0.7	Al	*3*
LE000021.D12	RE000021.D12	885	304		0.5 x 0.4	Al	*3*
LE000022.D12	RE000022.D12	400	256		0.7	Al	*1,2*
LE000023.D12	RE000023.D12	100	104		0.5	Al	*1,2,11*
LE000024.D12	RE000024.D12	347	243		0.4	Al foil	*2*
LE000025.D12	RE000025.D12	358	149		0.8	Al foil	*2,12*
LE000026.D12	RE000026.D12	129	315		0.9	Al	*1,2*
LE010001.D12	RE010001.D12	121	0	30	ND	Al	*1,2,13*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Impact into aluminum support grid.
2 - Features located on experiment A0023.
3 - Features located on experiment A0180.
4 - Features located on experiment A0019.
5 - Image taken at 30° to left and 8° above normal.
6 - Outer penetration diameter D2=~0.6 mm.
7 - No distinct feature.
8 - Image taken at 15° off of normal.
9 - Image taken at 10° below normal.
10 - Same image as LE000019.D12.
11 - Goosenecks entered into image file; should have been ring light.
12 - Photo taken of two impact features, diameter of small feature D=~0.2 mm.
13 - Photo taken to show spray pattern from image LE000026.D12.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-221/11, 108-KSC-384C-221/12, 108-KSC-384C-221/13
On-Orbit - S32-89-052
Pre-deintegration - KSC-390C-1069.04, KSC-390C-1069.06, KSC-390C-1069.10
Post Deintegration - KSC-390C-2002.12
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps -D12C01, D12C02, D12C04, and D12C05

LDEF LOCATION: E01
TRAY IDENTIFICATION: S0001
EXPERIMENT PURPOSE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. H. HUMES

493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay E01 held one of nineteen 3" (7.6 cm) deep, passive peripheral trays which were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 53 features on the E01 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of the 53 impact features found, 27 were <0.5 mm and were not imaged, 26 of which were located on the experimental aluminum surface, and one of which was located on the experiment-tray flange. Of the 26 imaged impact features, five were located on the tray flanges and ranged in size from 0.6 mm to 1.1 mm in diameter, one was located on the upper surface of the shim from clamp C01 and measured ~0.5 mm in diameter, and the remaining 20 features were located on the aluminum tray surface and ranged in size from 0.5 mm to 1.0 mm in diameter. All features were typical of craters produced in aluminum during laboratory hypervelocity impact tests.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm		1	26	27
>0.5 mm	1	5	20	26
TOTALS	1	6	46	53

The largest impact features identified on tray E01 were (1) a circular crater ~1.1 mm in diameter located on the tray wall, (2) a circular crater ~0.9 mm in diameter located on the upper tray flange, and (3) a circular crater ~0.9 mm in diameter (with ejecta spray) located on the aluminum tray surface.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment tray was mounted on the spacecraft. The M&D SIG identified one feature which might be damaged by the attachment of the experiment-tray cover and two additional features which could be damaged or destroyed by the placing of the experiment tray within the experiment-tray rotator stand. These latter features were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the most interesting feature within the experiment-tray cover area, the cover gasket was cut in one location to prevent it from coming into contact with this feature and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations of the 0.0625" (1.6 mm) thick experiment-tray flanges and no bulges or spalls on the back of the tray flanges. There were shadow features on the black painted back surface of the experiment tray.

DOCUMENTATION:

On March 6, 1990 the S0001 tray was inspected in the horizontal position using M&D SIG System #1. The detailed inspection of the clamps and bolts was also performed on March 6, on M&D SIG System #2. Impact coordinates for all features were determined using a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experimental-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC010001.E01	RC010001.E01	68	48		0.5	Al	*d,e*

Impact Features Imaged on Experimental-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000021.E01	RE000021.E01	254	950		0.9	Al	
LE000022.E01	RE000022.E01	175	0	-6	1.1	Al	*f,1*
LE000023.E01	RE000023.E01	408	0	-2	0.7	Al	*f,1*
LE000024.E01	RE000024.E01	487	0	-5	0.7	Al	*f,1*
LE000025.E01	RE000025.E01	630	0	-4	0.6	Al	*f,1*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.E01	RE000001.E01	588	224		0.5	Al	
LE000002.E01	RE000002.E01	498	247		0.6	Al	*k*
LE000003.E01	RE000003.E01	425	27		0.6	Al	
LE000004.E01	RE000004.E01	420	107		0.6	Al	
LE000005.E01	RE000005.E01	330	230		0.5 x 0.7	Al	
LE000006.E01	RE000006.E01	288	393		0.8	Al	
LE000007.E01	RE000007.E01	178	355		0.5	Al	
LE000008.E01	RE000008.E01	178	295		0.7	Al	*k*
LE000009.E01	RE000009.E01	160	142		0.6 x 0.8	Al	
LE000010.E01	RE000010.E01	58	457		0.6	Al	
LE000011.E01	RE000011.E01	28	697		0.8	Al	*x*
LE000012.E01	RE000012.E01	257	740		0.6	Al	*x*
LE000013.E01	RE000013.E01	267	745		1.0	Al	*d,x*
LE000014.E01	RE000014.E01	262	860		0.7	Al	*x*
LE000015.E01	RE000015.E01	555	835		0.9	Al	*x*
LE000016.E01	RE000016.E01	610	795		0.8	Al	*x*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000017.E01	RE000017.E01	652	625		0.6	Al	
LE000018.E01	RE000018.E01	925	555		0.5	Al	
LE000019.E01	RE000019.E01	975	745		0.6	Al	
LE000020.E01	RE000020.E01	1175	740		0.7	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Image taken from 35° above normal to crater.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-78-10
Pre-deintegration - KSC-390C-1066.08, KSC-390C-1069.01, KSC-390C-1069.03
Post Deintegration - KSC-390C-1657.12
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - E01C01, E01C02, E01C04, and E01C06
Clamp Bolts - E01S01C
Clamp Shims - E01H01

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION:	**E02**
TRAY IDENTIFICATION:	**A0178**
EXPERIMENT PURPOSE:	**A HIGH-RESOLUTION STUDY OF ULTRA-HEAVY COSMIC-RAY NUCLEI**
PRINCIPAL INVESTIGATOR:	**D. O'SULLIVAN DUBLIN INSTITUTE FOR ADVANCED STUDIES DUBLIN, IRELAND**

SUMMARY OF OBSERVATIONS

Bay E02 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46"-long (116.8 cm), 10" (25.4 cm) in diameter, 6063-T6 aluminum cylinders (1.9 mm thick) which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with an ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (space facing) of FEP Teflon (~120 μm thick) backed with a thin layer of vapor-deposited silver/inconel (~200 to 300 Å thick), which in turn was backed by DC1200 primer and Chemglaze Z306 black conductive paint (~80 to 100 μm thick). The blankets were attached to a 40-5052 aluminum support frame by ~1" x 2" (2.5 x 5.1 cm) strips of velcro.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of the resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted teflon material. Commonly, the teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. Many possessed several sharp, distinct rings, while others exhibited a more continuous halo phenomenon where the change from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impact craters into aluminum.

The M&D SIG survey identified a total of 121 features on the E02 experiment tray including the experiment-tray bolts, clamps, shims, and flanges. Of the 121 impact features found, 15 were located on the tray flanges, bolts, and clamps and were not imaged due to the feature size being less than the threshold limit of 0.5 mm. Only two impacts were found on the aluminum tray flanges which met the photodocumentation threshold limit and were imaged. Eighty-seven impacts were found on the thermal insulation blanket and were not imaged due to the penetration diameters being less than the threshold limit of 0.3 mm. Seventeen impacts were imaged on the thermal insulation blanket and ranged in diameter from 0.3 mm to 0.5 mm.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			87	87
>0.3 mm			17	17
<0.5 mm	5	10		15
>0.5 mm		2		2
TOTALS	5	12	104	121

The largest impact feature identified on tray E02 was a circular penetration ~0.5 mm in diameter through the thermal blanket.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 20, 1990 while the experiment tray was mounted on the spacecraft. The M&D SIG identified two features which might be damaged by the attachment of the experiment-tray cover. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations of the 0.125" (3.2 mm) thick experiment-tray flanges and no bulges or spalls on the back of the tray flanges.

DOCUMENTATION:

On March 28, 1990 tray E02 was inspected in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #1. The bolts, clamps, and shims associated with this tray were scanned with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale.

Bolt-Hole Registration (mm)

	TOP X	TOP Y	BOTTOM X	BOTTOM Y
Far Left	55	948	55	-26
Center	613	950	614	-24
Far Right	1171	952	1171	-22

Fiducial Mark Locations (mm)

	TOP X	TOP Y	BOTTOM X	BOTTOM Y
Far Left	214	897	231	-29
Center	624	896	613	-28
Far Right	1008	901	1005	-25

Impact Features Imaged on Experimental-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	IMAGE FILE NAMES RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000015.E02	RE000015.E02	1260	755		0.7	Al	1
LE000016.E02	RE000016.E02	708	-26		0.8	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.E02	RE000001.E02	202	754		0.4	TB	
LE000002.E02	RE000002.E02	463	729		0.4	TB	
LE000003.E02	RE000003.E02	462	877		0.4	TB	
LE000004.E02	RE000004.E02	506	847		0.4	TB	
LE000005.E02	RE000005.E02	833	796		0.5	TB	
LE000006.E02	RE000006.E02	1137	546		0.4	TB	
LE000007.E02	RE000007.E02	1126	530		0.5	TB	
LE000008.E02	RE000008.E02	1012	483		0.3	TB	
LE000009.E02	RE000009.E02	802	584		0.3	TB	*2*
LE000010.E02	RE000010.E02	637	484		0.4	TB	
LE000011.E02	RE000011.E02	952	311		0.4	TB	
LE000012.E02	RE000012.E02	904	344		0.4	TB	
LE000013.E02	RE000013.E02	693	307		0.3	TB	
LE000014.E02	RE000014.E02	313	305		0.3	TB	
LE000017.E02	RE000017.E02	147	222		0.5	TB	*3*
AE000017.E02	BE000017.E02	147	222		0.5	TB	
LE000018.E02	RE000018.E02	146	189		0.3	TB	
AE000018.E02	BE000018.E02	146	189		0.3	TB	
LE000019.E02	RE000019.E02	203	136		0.4	TB	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

TB - Thermal Blanket (Teflon, silver-inconel, binder, and paint)

1 - Illumination with left gooseneck only.
2 - No apparent rings or rim around penetration.
3 - Right image bad in stored file.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-403/1
On-Orbit - S32-89-018
Pre-deintegration - KSC-390C-1065.07, KSC-390C-1065.09, KSC-390C-1065.11
Post Deintegration - KSC-390C-2336.02, KSC-390C-2336.12
M&D SIG Photos - S-90-43566, S-90-43567 - Left 1/3 of Thermal Blanket; angled front and backlit back views.
S-90-43568, S-90-43569 - Middle 1/3 of Thermal Blanket; angled front and backlit back views.
S-90-43572, S-90-43573 - Right 1/3 of Thermal Blanket; angled front and backlit back views.

ARCHIVED MATERIALS:

Clamps - E02C01, E02C02, E02C04, and E02C05
Thermal Blanket - (E02E00A) - The U.S. third (minus the Materials SIG specimen) resides at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds (minus the Materials SIG grounding-strap specimen) are being archived at ESTEC in The Netherlands. Each blanket third was marked with two small crosses (see Fiducial Mark table above) for indexing and reconstruction purposes.

LDEF LOCATION:	**E03**
EXPERIMENT IDENTIFICATION:	**S1002**
EXPERIMENT TITLE:	**INVESTIGATION OF CRITICAL SURFACE DEGRADATION EFFECTS ON SOLAR CELLS DEVELOPED IN GERMANY**
PRINCIPAL INVESTIGATOR:	**L. PREUSS** **MBB SPACE DIVISION** **FEDERAL REPUBLIC OF GERMANY**
	A0187-2
	CHEMICAL AND ISOTOPIC MEASUREMENT OF MICROMETEOROIDS BY SECONDARY ION MASS SPECTROMETRY
	E. ZINNER **WASHINGTON UNIVERSITY** **ST. LOUIS, MISSOURI 63130**

SUMMARY OF OBSERVATIONS

One-third of the 6"-deep (15.2 cm) experiment tray occupying Bay E03 contained the active experiment S1002, which consisted of samples of solar-cell materials and coatings mounted in an experiment environment control cannister (EECC) which was programmed to open shortly after the deployment of LDEF and to close ~11 months later. The aluminum EECC was closed when LDEF was recovered and only the exterior surfaces were examined for the presence of impact features by the M&D SIG.

The remaining two-thirds of the experiment tray in Bay E03 was covered with the passive A0187-2 micrometeoroid collector. This experiment consisted of 77 capture cells, each composed of four 38 x 42 mm, 0.5 mm thick germanium crystal wafers which were bonded with 1 mm thick strips of silicone RTV to an 86 x 94 mm, 3 mm thick 6061-T6 aluminum backplate; each cell was covered with a 2 μm thick metallized (200 Å Au/Pd exterior, 1000 Å Ta interior) Mylar foil. There were two additional trays on LDEF with A0187-2 germanium capture cells at locations A02 and E08. The meteoroid capture cells were attached to a mounting plate constructed from sandwiched (2.5 cm spacing) 0.5 mm thick aluminum.

Only 11 out of a total of 77 of the mylar foils were still intact following the retrieval of the LDEF spacecraft. This compares to one out of 40 and zero out of 120 for trays A02 and E08, respectively. The broken foils were still attached to the capture-cell frames in many places, the majority of which had rolled up into coils which looked like shards and projected at all angles away from the surface. Some of this material came off during the LDEF rotation operations, contaminating other surfaces. The front of the M&D SIG microscopes had to be wiped down with anti-static pads to avoid attracting the mylar shards.

Impacts into aluminum surfaces were morphologically typical of hypervelocity impacts into this material, with the exception of the large hole (~1.8 x 3.4 mm) in the 0.5 mm thick aluminum sandwich structure which represented the largest penetration feature found on the entire LDEF spacecraft. This was a highly oblique impact into relatively thin metal and did not possess a very prominent raised rim. The bottom layer of the sandwich structure was separated from the top layer by a 25 mm thick honeycomb structure and exhibited two small bulges which appeared to be associated with this oblique feature. There was a large amount of ejecta associated with this feature as well, both on the target surface and on the edge of an adjacent germanium capture-cell frame. The ejecta looked like molten aluminum and had no other visibly distinguishable features.

Impacts into germanium were typical of crystalline material impacts, with a central crater surrounded by a front-surface spallation zone and an extensive fracture zone. See Section 2.B. for a detailed description of this phenomenon. Some impacts, which apparently occurred when the mylar foils were still intact, had associated debris rings surrounding them. Because this experimental surface was designed to disrupt incoming hypervelocity particles, the number and size of impact features should not be comparable to those observed on other surfaces with equivalent positions on LDEF. Furthermore, the uncovered germanium surfaces were contaminated with bits of the broken mylar foils and particles of the metal coatings from the foils. This made it extremely difficult to count small features, and some contamination features which were not actual impacts may have been counted as small features.

The M&D SIG survey visually identified a total of 122 features on the entire experiment-tray surface. Six features in the 0.2 - 0.3 mm size range were found on three different 0.19" (4.8 mm) thick, chromic anodized 6061-T6 aluminum tray clamps. Of the remaining 116 features, 105 were much smaller than 0.5 mm and were not imaged. No information on the general locations (*i.e.*, experiment-tray flanges, walls or experimental surfaces) of the <0.5 mm diameter features was recorded. Ten features were imaged, including four which were <0.5 mm but were of interest because of the scarcity of large impacts on the germanium surfaces. One feature out of the 122, with an estimated diameter between 0.5 and 1.0 mm, was located between the tray wall and the A0187-2 mounting plate and could not be imaged. This was the only large impact on the experiment-tray flange and wall surface areas.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	6			115*
>0.5 mm		1	6	7
TOTALS	6			122*

* The location of the "Too Smalls" was not documented.

The largest features identified on Tray E03 were (1) an ~1.8 x 3.4 mm hole in the 0.5 mm thick aluminum mounting plate (LE000007.E03), (2) an ~2 mm hole in a germanium wafer (LE000004.E03), and (3) an ~1.5 mm crater in aluminum with associated debris (LE000009.E03).

M&D SIG INSPECTIONS

PRE-DEINTEGRATION:

The initial inspection was conducted on February 20, 1990 while the experiment tray was mounted on the spacecraft. No impact features >0.5 mm in diameter were visually identified on the tray clamps, shims, bolts or flanges during the on-satellite inspection of tray E03.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick, chromic-anodized, 6061-T6 aluminum experiment-tray flanges.

DOCUMENTATION:

Tray E03 was inspected and features documented on March 9, 1990 using M&D SIG System #2 and Coordinate Registration System #2. Tray clamps, bolts and shims were also inspected on March 9 using M&D SIG System #3, but no images were taken. The outer corners of the four A0187-2 capture cells positioned at the corners of their mounting plates were marked with a dot of black ink and the X,Y-coordinates recorded for reference. These fiducial marks are listed below.

Bolt-Hole Registration - Not Determined

A0178-2 Mounting Plate Fiducial Mark Locations (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Left	442	897	440	45
Right	1224	897	1222	44

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.E03	RE000001.E03	245	420		0.8	Al tape	
LE000002.E03	RE000002.E03	556	663		0.5	Ge	*b,d*
LE000003.E03	RE000003.E03	637	623		0.3	Ge	*b,d*
LE000004.E03	RE000004.E03	737	504		2.0	Ge	*1,b,m*
LE000005.E03	RE000005.E03	1128	587		0.1	Ge	*b,d*
LE000006.E03	RE000006.E03	1166	502		0.2	Ge	*b*
LE000007.E03	RE000007.E03	1232	701		1.8 x 3.4	Al	*1,d,e,h*
LE000008.E03	RE000008.E03	1231	597		0.7	Al	
LE000009.E03	RE000009.E03	1073	53		0.1	Mylar	
LE000010.E03	RE000010.E03	9	415	130	1.5	Al	g
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Penetration of target material.

OTHER PHOTODOCUMENTATION:

Pre-Flight - KSC-383C-4209/6
On-Orbit - S32-82-19, S32-77-067
Pre-Deintegration - KSC-390C-1065.01, KSC-390C-1065.03, KSC-390C-833.10
Post Deintegration - KSC-390C-1839.02
M&D SIG Photos - None

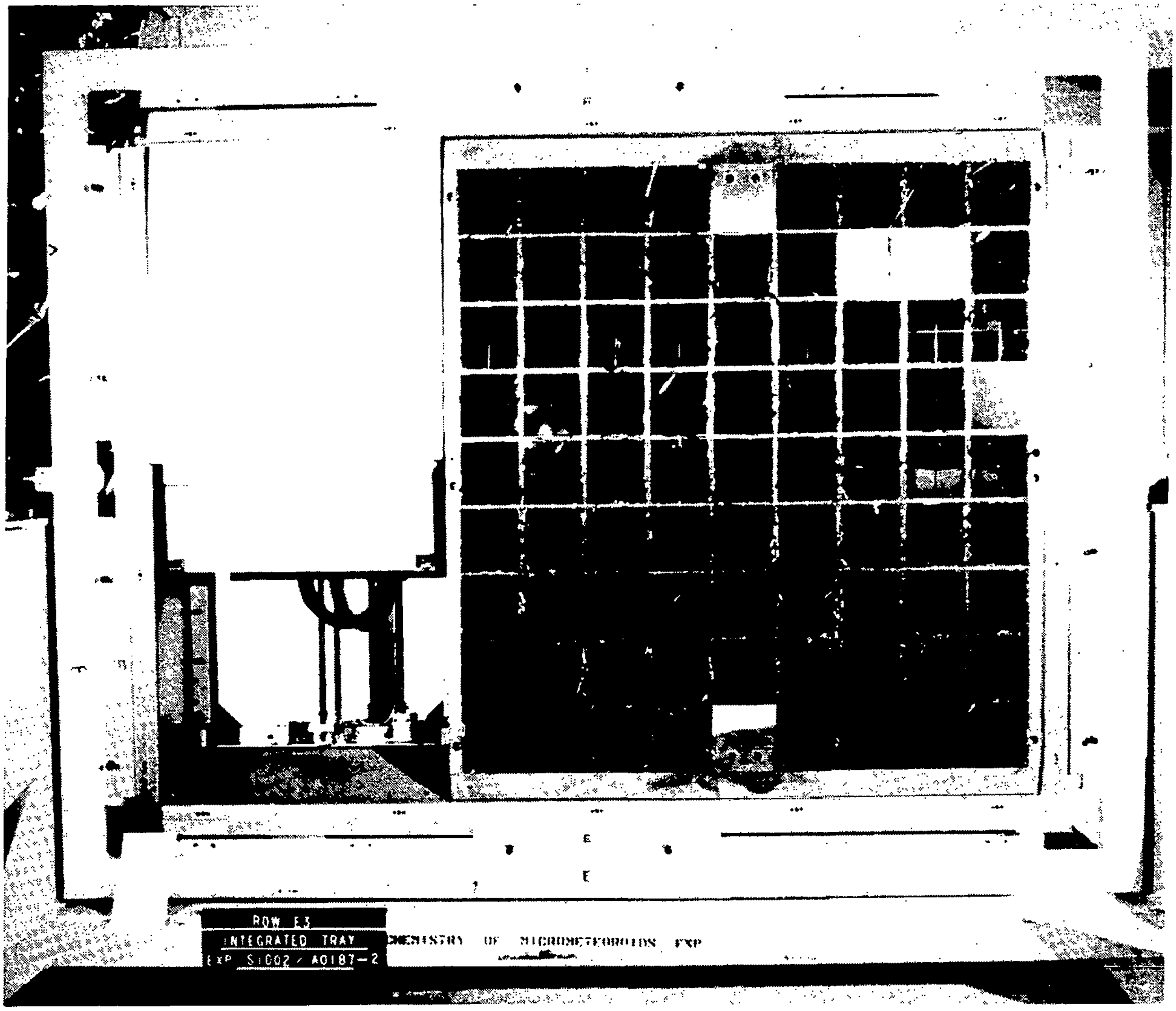
ARCHIVED MATERIALS:

Clamps - E03C02, E03C04, E03C05, and E03C07

Feature LE000007.E03 (the largest impact induced hole in LDEF) has been assigned by the hardware owner (MBB) for donation to the M&D SIG, and subsequent curation at JSC, following experiment deintegration.

ACCOMPANYING FIGURES:

Figure E03-1. This post-deintegration view shows the front of the entire E03 experiment tray.


ROW E3
INTEGRATED TRAY
EXP S1002 / A0187-2
CHEMISTRY OF MICROMETEOROIDS EXP

LDEF LOCATION:	**E04**
EXPERIMENT IDENTIFICATION:	**S0001**
EXPERIMENT TITLE:	**SPACE DEBRIS IMPACT EXPERIMENT**
PRINCIPAL INVESTIGATOR:	**D. HUMES**
	493 NASA LANGLEY RESEARCH CENTER
	HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay E04 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays which were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 45 features on the E04 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of these, 33 features from all surfaces were found to be smaller in diameter than the 0.5 mm photodocumentation threshold. Eight features were photodocumented from the aluminum collector surfaces, seven of which were between 0.5 mm and 1.0 mm in diameter, and one of which was between 1.0 mm and 1.5 mm in diameter. Two features which measured between 0.5 mm and 1.0 mm in diameter were found on the tray flanges, one of which was not photodocumented due to hardware problems encountered with the imaging system. An additional feature measuring ~0.4 mm in diameter resided on the 3" (7.6 cm) high inner-tray wall and was photodocumented. Only three features were identified on the various clamping hardware (one feature each on clamps C03, C04, and C08) associated with this tray, all of which were <0.5 mm in diameter and were not photodocumented. All features exhibited characteristics typical of craters formed in aluminum during laboratory hypervelocity impact experiments.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	3			35*
>0.5 mm		2	8	10
TOTALS	3			45*

* The location of the "Too Smalls" was not documented.

The largest impact features identified were (1) an ~1.1 mm diameter crater on the aluminum collector surface and (2) an ~1.1 mm crater from the experiment-tray flanges.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection (February 22, 1990) was conducted while the experiment tray was mounted on the spacecraft and identified two features which might be damaged by the emplacement of the experiment-tray cover. Only one feature was found on the outer tray flanges which could be damaged by placing the experiment tray within the experiment-tray rotator stand clamping mechanism. This feature was not examined

or photodocumented, but it was included in the numerical summary given above. During this initial survey only one feature on clamp C08 was identified.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations or spallation features on the 0.0625" (1.6 mm) thick experiment-tray flanges. Minor shadowing effects were noted on the experiment-tray back side.

DOCUMENTATION:

Examination and photodocumentation of tray E04, including the bolts, clamps, and shims associated with this tray, were conducted on February 27, 1990 in the horizontal position utilizing M&D SIG System #3. The coordinates for all features associated with this tray were measured with a metric scale. A stain-like coloration was noted, predominantly in the corners of the experimental surfaces of the S0001 aluminum collectors. Microscopic inspection of this area could not reveal the make-up or source for this discoloration.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.E04	RE000001.E04	116	977		1.1	Al	*x*
LE000010.E04	RE000010.E04	321	-1		0.4	Al	*1,f,x*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.E04	RE000002.E04	570	785		0.8	Al	*x*
LE000003.E04	RE000003.E04	420	490		0.8	Al	*x*
LE000004.E04	RE000004.E04	492	72		0.6	Al	*2*
LE000005.E04	RE000005.E04	650	425		0.7	Al	
LE000006.E04	RE000006.E04	832	300		0.5	Al	*3*
LE000007.E04	RE000007.E04	940	18		0.6	Al	
LE000008.E04	RE000008.E04	1095	785		0.6	Al	*x*
LE000009.E04	RE000009.E04	1115	795		1.1	Al	*x*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - No Z coordinate recorded.
2 - Image taken at 10° from normal of crater.
3 - Image rotated 30° counter-clockwise.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-77-048
Pre-Deintegration - KSC-390C-1065.06, KSC-390C-1065.05, KSC-390C-832.03
Post Deintegration - KSC-390C-1654.10
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - E04C01, E04C03, E04C04, and E04C08

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION: E05
EXPERIMENT IDENTIFICATION: S0050
EXPERIMENT TITLE: INVESTIGATION OF THE EFFECTS OF LONG DURATION EXPOSURE ON ACTIVE OPTICAL SYSTEM COMPONENTS
PRINCIPAL INVESTIGATOR: M. BLUE
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

A0135
EFFECTS OF SPACE EXPOSURE ON PYROELECTRIC INFRARED SENSORS
J. ROBERTSON
NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

A0044
HOLOGRAPHIC DATA STORAGE CRYSTALS FOR LDEF
W. CALLEN
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GEORGIA 30332

SUMMARY OF OBSERVATIONS

Bay E05 contained a 6"-deep (15.2 cm) experiment tray which housed three experiments which exposed various optical components to the low-Earth orbital environment. The Investigation of the Effects of Long Duration Exposure on Active Optical System Components experiment (S0050) consisted of a total of 136 passive and active optical components and detectors, all passively mounted on 6061-T6 aluminum sheets, bars, or rods beneath a 0.125" (3.2 mm) thick, 6062-T52 aluminum sunscreen (~50% open area). The upper left sixth of the tray was the only portion of the experimental surface area which was not covered by one of these aluminum sunscreen. Another 20 pyroelectric detectors, comprising the Effect of Space Exposure on Pyroelectric Infrared Detector experiment (A0135), were included in the same specimen mounting area. Four 10 cm^2 holographic storage crystals were also mounted in this tray and made up the Holographic Data Storage Crystals for LDEF experiment (A0044).

The M&D SIG survey identified a total of 121 features on experiment-tray surfaces, including ten on the 0.19" (4.8 mm) thick, 6061-T6 chromic anodized aluminum tray clamps. Two features on tray clamps were >0.5 mm in diameter and were imaged. Of the 111 features on the tray itself, 47 were on the experiment-tray flanges, and only five of these were >0.5 mm in diameter. Four out of the 64 features on the experiment surface area were >0.5 mm in diameter. All of the impact features which were >0.5 mm in diameter were located on aluminum surfaces and were morphologically typical of hypervelocity impacts in this material.

One impact feature was located on the inside of the lower-left sunscreen. This was not imaged until the sunscreen was deintegrated from the experiment tray. At that time, the sunscreen was assigned the component identifier of "E01".

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	8	42	60	110
>0.5 mm	2	5	4	11
TOTALS	10	47	64	121

The largest impact features identified on tray E05 were (1) an ~1.2 mm diameter crater (LE010001.E05) on the inside edge of one of the holes in the lower-left sunscreen and (2) an ~1.4 mm diameter crater (LC030001.E05) on clamp C03.

M&D SIG INSPECTIONS

PRE-DEINTEGRATION:

Five impact features >0.5 mm in diameter were found on the experiment-tray clamps, and one feature was found on the experiment-tray flange during the visual inspection of tray E05 conducted on February 22, 1990, while it was still mounted on the LDEF. None of the experiment-tray clamp features were in an area which would be subjected to contact by the experiment-tray cover gasket or the tools used in the tray removal process. However, the feature on the experiment-tray flange would be destroyed by the experiment-tray rotator stand clamping mechanism. This feature was not examined or photodocumented, nor was it included in the numerical summary given above.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick, chromic-anodized, 6061-T6 aluminum experiment-tray flanges.

DOCUMENTATION:

Tray E05 was inspected in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #3 on March 19, 1990. The tray clamps, bolts, and shims were inspected on the same day and imaged with M&D SIG System #3. The sunscreens were removed and the bottom of the tray was reinspected on March 20, 1990. An additional eight features, all <0.5 mm in diameter, were found during this inspection and are included in the totals discussed above.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC030001.E05	RC030001.E05	13	24		1.4	Al	
LC050001.E05	RC050001.E05	102	0		0.6	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.E05	RE000001.E05	0	915		0.6	Al	*1,2*
LE000002.E05	RE000002.E05	580	940		0.6	Al	*1*
LE000003.E05	RE000003.E05	920	940		0.5	Al	*1*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000004.E05	RE000004.E05	80	940		0.8	Al	*1*
LE000008.E05	RE000008.E05	360	30		0.8	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000005.E05	RE000005.E05	20	725		0.6	Al	
LE000006.E05	RE000006.E05	445	660		0.5	Al	
LE000007.E05	RE000007.E05	455	340		0.6	Al	
LE010001.E05	RE010001.E05	135	210		1.2	Al	*3*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Feature located inside of bevel on experiment-tray flange.
2 - Wrong coordinates (X = 80, Y = 940) entered with image file.
3 - Feature located on edge of a hole in sunscreen, camera angle of ~28° above normal to crater.

OTHER PHOTODOCUMENTATION:

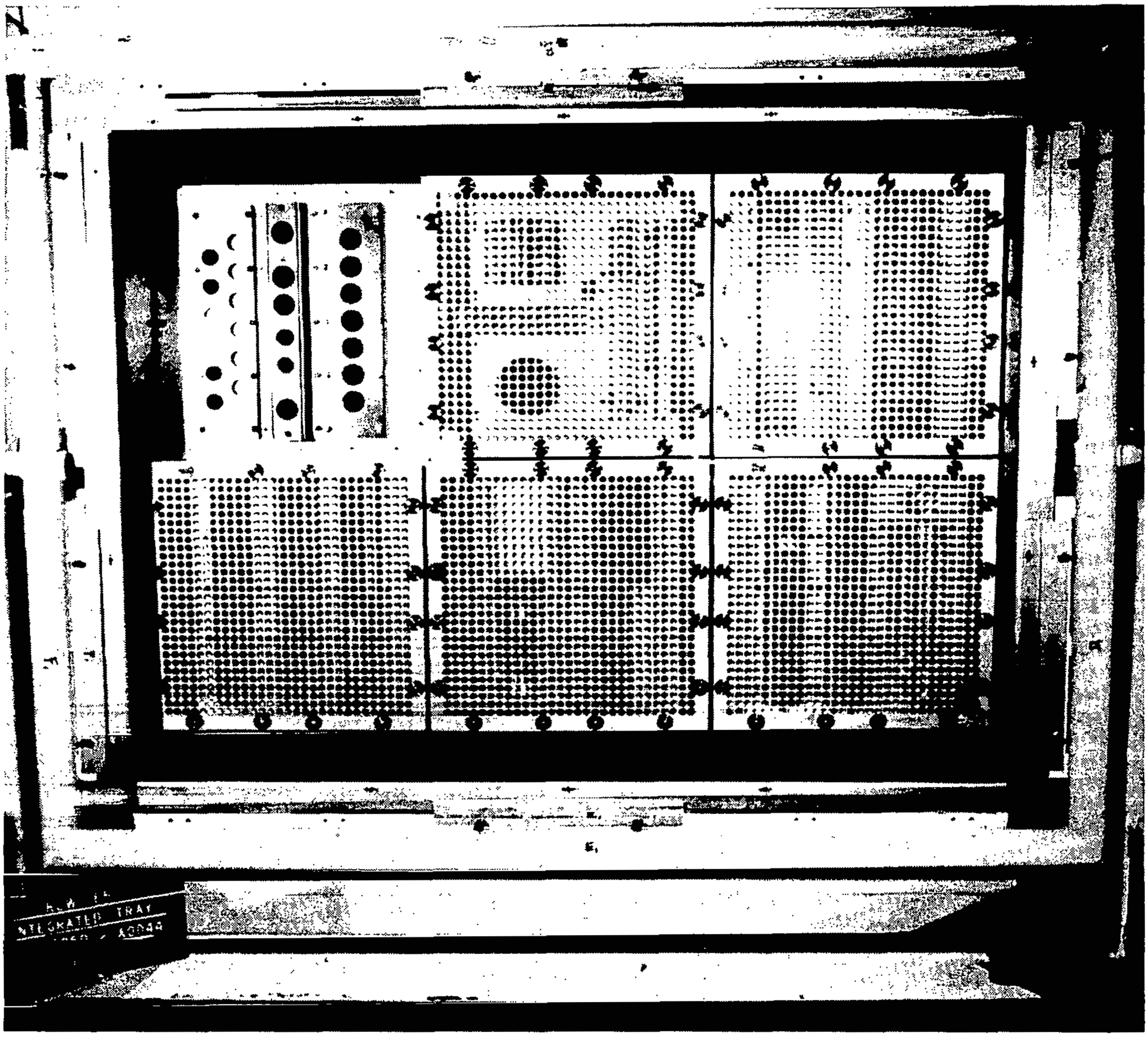
Pre-Flight - 108-KSC-384C-255/6
On-Orbit - S32-77-050
Pre-Deintegration - KSC-390C-1035.10, KSC-390C-1035.12, KSC-390C-1035.05
Post Deintegration - KSC-390C-2113.05, KSC-390C-2114.03
M&D SIG Photos - S90-43441 - Picture of a flea (deceased) on clamp C02, appropriately titled "Flea T."

ARCHIVED MATERIALS:

Clamps - E05C03, E05C04, E05C05, and E05C07
Other - E05E01 and E05E02 - Aluminum sunscreens

ACCOMPANYING FIGURES:

Figure E05-1. This post-deintegration view shows the front of the entire E05 experiment tray. Partially transparent aluminum "sunscreens" cover five-sixths of the tray. The tray elements below these sunscreens were not surveyed by the M&D SIG at KSC in 1990.



LDEF LOCATION:	**E06**
EXPERIMENT IDENTIFICATION:	**A0023**
EXPERIMENT TITLE:	**MULTIPLE-FOIL MICROABRASION PACKAGE**
PRINCIPAL INVESTIGATOR:	**J.A.M. McDONNELL** **UNIT FOR SPACE SCIENCES** **UNIVERSITY OF KENT** **CANTERBURY, UNITED KINGDOM CT28EF**
	S1003 **ION-BEAM-TEXTURED AND COATED SURFACES EXPERIMENT** **M. MIRTICH, JR.** **NASA LEWIS RESEARCH CENTER** **CLEVELAND, OHIO**
	S1006 **BALLOON MATERIALS DEGRADATION** **D.H. ALLEN** **TEXAS A&M UNIVERSITY** **COLLEGE STATION, TEXAS**
	M0002-2 **MEASUREMENT OF HEAVY COSMIC-RAY NUCLEI ON LDEF** **R. BEAUJEAN** **UNIVERSITY OF KIEL** **KIEL, FEDERAL REPUBLIC OF GERMANY**

SUMMARY OF OBSERVATIONS

Bay E06 contained a 3"-deep (7.6 cm), integrated, passive experiment tray which housed one meteoroid/debris-type experiment (A0023), an experiment for the study of optical properties degradation (S1003), a materials degradation experiment (S1006), and an experiment to measure the elemental and isotopic abundances of heavy cosmic-rays (M0002-2).

The A0023 experiment was designed to measure the density (flux), size, velocity, radial distribution, and composition of micro-particles in low-Earth orbit. The detectors exposed rolled aluminum foils as thin as 1.5 μm which were bonded to etched aluminum grids to support the foils and provide a rugged structure. The experiment was located in one-third sections of four trays (C03, E06, C09, and D12) spaced at 90° intervals around the periphery of the spacecraft, as well as two-thirds of one 3"-deep (7.6 cm) space-facing tray (H11).

Experiment S1003 exposed high absorptance solar thermal-control surfaces which had been textured *via* an ion beam. The purpose of the experiment was to investigate the changes in the optical and electrical properties of these materials, and to measure the mass loss of the ion-deposited oxide-polymer film. Exposed materials included inconel, copper, aluminum, stainless steel, silver, Teflon, and black and silver painted

thermal surfaces, as well as kapton-coated indium oxide, aluminum, and chromium. A detailed listing of the exposed samples can be found on pages 64 and 65 of the *The Long Duration Exposure Facility (LDEF) Mission 1 Experiments* handbook (NASA SP-473). The experiment consisted of a one-sixth tray sized aluminum box and cover plate; forty two, 2 cm diameter holes in the cover plate exposed the 36 different materials to the low-Earth orbit environment.

The scientific objective of the S1006 materials experiment was to expose high-altitude, candidate balloon materials (films, tapes, and lines) to the effects of near-Earth space and to measure the changes in their physical properties as a result of this exposure. The experiment occupied the center one-third of the E06 tray and exposed approximately 25 test specimens including reinforced polyesters, Stratofilms, nylon, and kevlar (see page 50 of *The Long Duration Exposure Facility [LDEF] Mission 1 Experiments* handbook [NASA SP-473] for a detailed list of materials).

The M0002-2 experiment was designed to measure the elemental and isotopic abundances of heavy cosmic-ray nuclei with a nuclear charge $Z \geq 3$. The experiment was located in the lower right-hand one-sixth of the E06 tray and consisted of visual track detectors which were to remain sensitive throughout the LDEF mission; each detector stack consisted of 6.5 g/cm^2 of CR-39 plastic sheets. The detectors were housed in an aluminum canister which was covered by a thermal control blanket to provide thermal isolation of the experiment.

Penetrations through the aluminum foils of A0023 and the thermal control blanket of M0002-2 varied from circular to elongate in shape. One impact on A0023 into the wire grid deposited debris across the surface of the aluminum foil. Features found within the various aluminum surfaces of Tray E06 were typical of those produced in similar material under controlled, hypervelocity laboratory conditions. The materials on S1006 were extremely degraded as a result of the long-term exposure and so little morphologic information was available on these materials.

The M&D SIG survey identified a total of 202 features on Tray E06 including the experiment-tray bolts, clamps, shims, and flanges, as well as all experimental surfaces. The distribution (*i.e.*, experimental surfaces versus experiment-tray hardware) of the features smaller than the M&D SIG threshold values was not recorded for this tray; a total of 180 features fall into this category. Of that 180 features, 13 features <0.5 mm were identified on the various clamps associated with this tray. Seven of the photodocumented or examined features were <0.3 mm in diameter and represented penetrations through various experimental materials; only one "Too Small" feature was identified on an aluminum surfaces during the examination microscopic phases. Ten penetrations were photodocumented, one of which was between 1.0 and 1.5 mm in diameter and nine of which were between 0.5 and 1.0 mm in diameter. Four features >0.5 mm were photodocumented on various aluminum experimental surfaces or hardware (three between 0.5 and 1.0 mm and one between 1.0 and 1.5 mm in diameter). Three features found during the detailed microscopic examination of the various clamps (one each on clamps C02, C04, and C05) were photodocumented, all between 0.5 and 1.0 mm in diameter.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm				*
>0.3 mm			8	8
<0.5 mm	13			*
≥0.5 mm	3	3	4	10
TOTALS	16			202*

* The location of the "Too Smalls" was not documented.

The largest impact features identified were (1) an ~1.5 mm diameter crater on top, inner tray wall, (2) an ~1.1 mm penetration hole in the A0023 aluminum foil, (3) an ~1.1 mm crater on an aluminum surface of S1003, and (4) ~0.6 mm diameter craters on clamps C02 and C04.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection (February 22, 1990) was conducted while the experiment tray was mounted on the spacecraft. Four features were identified which might be damaged by the emplacement of the experiment-tray cover and two additional features were found which could be damaged or destroyed by the placing of the experiment tray within the experiment-tray rotator stand. These latter features were not examined or photodocumented, but they are included in the numerical summary given above. None of the features within the experiment-tray cover area were of significant size to warrant cutting the experiment-tray cover gasket. Two features were found on clamps C02 and C05, while one feature each was identified on clamps C04, C06, and C07; one feature was also identified on bolt C08B.

GENERAL FRONT AND BACKSIDE:

Although a bulge was later identified, at the time of the inspection there were no identified penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of tray E06 was conducted on March 14 and 15, 1990 in the vertical position utilizing M&D SIG System #3; the bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3, as well. The coordinates for all features examined on this tray were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC020001.E06	RC020001.E06	85	10		0.6	Al	
LC040001.E06	RC040001.E06	26	86		0.6	Al	*k*
LC050001.E06	RC050001.E06	47	3		0.5	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000022.E06	RE000022.E06	679	966		0.9	Al	
LE000024.E06	RE000024.E06	320	964		0.7	Al	
LE000025.E06	RE000025.E06	273	945		1.5	Al	*9,f,h*
AE000025.E06	BE000025.E06	273	945		1.5	Al	*5,f,h*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.E06	RE000001.E06	1045	75		0.6	TB	*4,6*
LE000002.E06	RE000002.E06	935	152		0.5 x 0.6	TB	*4,6*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000003.E06	RE000003.E06	892	275		0.4	TB	*4,6,8*
LE000004.E06	RE000004.E06	1201	457		0.4	TB	*4,6*
LE000005.E06	RE000005.E06	1199	279		0.2	TB	*4,6*
LE000006.E06	RE000006.E06	1230	184		0.5	TB	*4,6,7,8*
LE000007.E06	RE000007.E06	672	153		0.3 x 0.4	Tape?	*3,6*
LE000008.E06	RE000008.E06	547	311		0.2	Tape?	*3,6*
LE000009.E06	RE000009.E06	364	205		0.5 x 0.6	Al	*1,6*
LE000010.E06	RE000010.E06	91	266		0.3	Al	*1,10,d*
LE000011.E06	RE000011.E06	268	366		ND	Al	*1,11*
LE000012.E06	RE000012.E06	151	402		0.2	Al	*1,12*
LE000013.E06	RE000013.E06	286	553		ND	Al	*1,13*
LE000014.E06	RE000014.E06	277	546		0.6	Al	*1*
LE000015.E06	RE000015.E06	124	750		ND	Al	*1,13*
LE000016.E06	RE000016.E06	355	606		0.3	Al	*1,10*
LE000017.E06	RE000017.E06	955	722		0.3	Kapton	*2,6*
LE000018.E06	RE000018.E06	1169	776		1.1	Al	*2*
LE000019.E06	RE000019.E06	921	808		0.5	Al	*2,k*
LE000020.E06	RE000020.E06	1222	950		0.6	Al	*2*
LE000021.E06	RE000021.E06	1014	906		0.1	Si?	*2,14*
LE000023.E06	RE000023.E06	89	900		1.1	Al	*1,6,10*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined
TB - Thermal Blanket (aluminized kapton?)

1 - Feature located on experiment A0023.
2 - Feature located on experiment S1003.
3 - Feature located on experiment S1006.
4 - Feature located on experiment M0002-2.
5 - Images AE000025.E06 and BE000025.E06 are stereo pair of bulge on back surface of experiment tray; images acquired using 0.4 mm lower objective.
6 - Penetration through material.
7 - No coordinates input with image file.
8 - No diameter information recorded in logbook.
9 - Image taken 5° to the right and 30° above normal of crater.
10 - Penetration through aluminum support grid structure.
11 - Crater in glue, no measurable feature.
12 - Projectile grazed aluminum support grid prior to aluminum foil penetration.
13 - Possible defect in aluminum foil, not a penetration or questionable penetration.
14 - Questionable penetration in Row 1, Disk #3 material.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-84-7068
On-Orbit - S32-82-40
Pre-Deintegration - KSC-390C-1033.01, KSC-390C-1003.03, KSC-390C-1003.09
Post Deintegration - KSC-390C-1992.03, KSC-390C-1994.12
M&D SIG Photos - None

ARCHIVED MATERIALS:

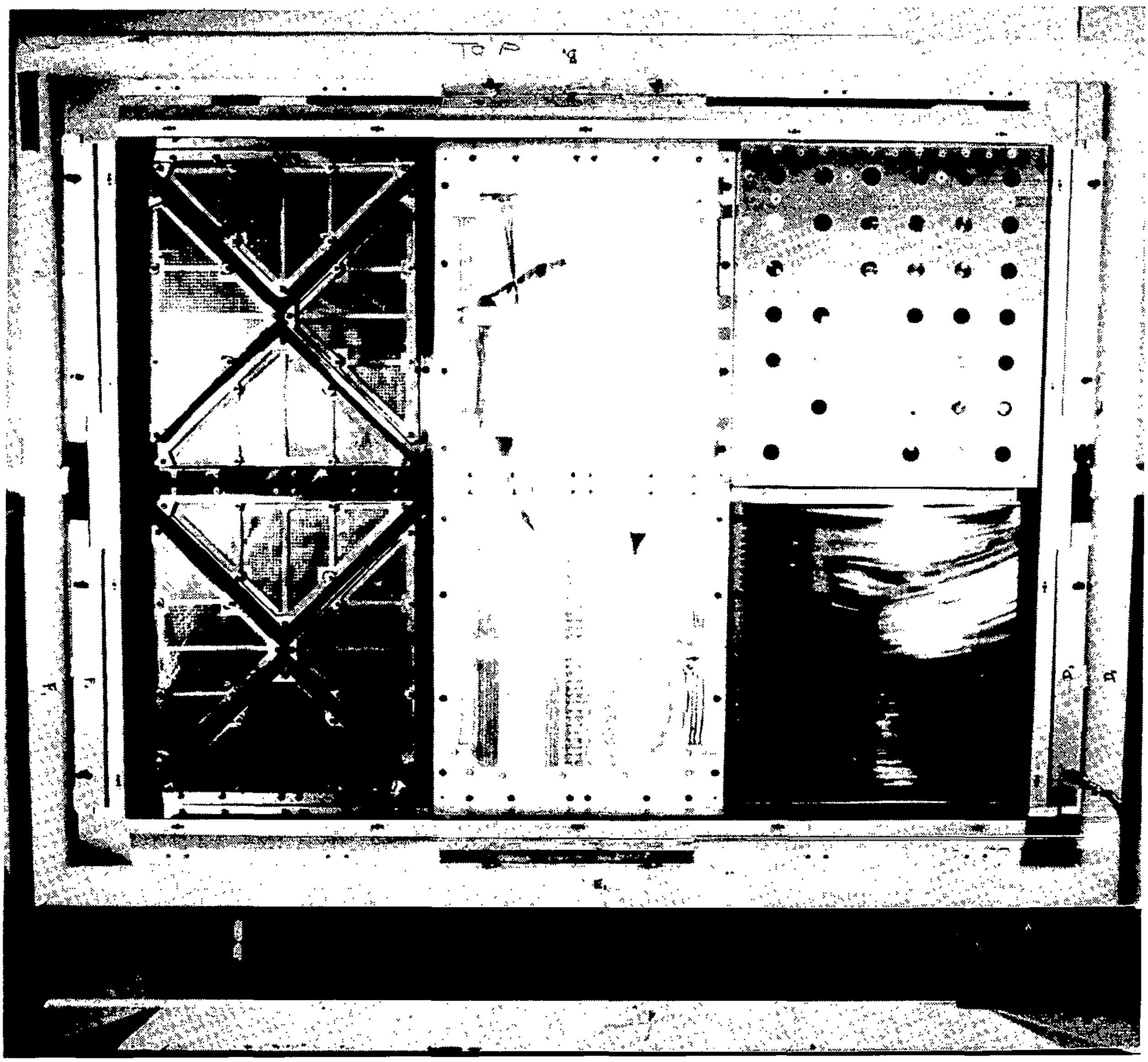
Clamps - E06C02, E06C04, E06C05, and E06C07
Clamp Bolts - E06S08B
Other - E06E00A - M0002-2 Thermal Blanket - Was loaned to M&D SIG for detailed scanning and examination; PI retains rights to material.

Corners of M0002-2 Experiment With Respect to 0,0 (mm)
Measurements made with metric tape measure.

	X	Y
Top Left	86	453
Bottom Left	86	22
Top Right	1236	453
Bottom Right	1236	22

ACCOMPANYING FIGURES:

Figure E06-1. This post-deintegration view shows the front of the entire E06 integrated experiment tray.



LDEF LOCATION: E07
EXPERIMENT IDENTIFICATION: S0001
EXPERIMENT TITLE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES
493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

This 3"-deep (7.6 cm) passive experiment tray is one of 25 whole or partial trays which make up the Space Debris Impact Experiment. The S0001 experiment hardware consists of aluminum plates (6061-T6 anodized aluminum) each 0.1875" (4.8 mm) thick. The plates have a thin chromic anodized coating on both sides and a coat of black paint on the back side for thermal control. The experiment, occupied nineteen 3"-deep (7.6 cm) peripheral trays, two 3"-deep (7.6 cm) end corner trays on the Earth-facing end, and one 3"-deep (7.6 cm) end corner tray on the space-facing end of the LDEF. Additionally, several partial tray locations on the periphery were utilized. An S0001 experiment tray was located on all rows except Row 9, the leading edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 282 features on the E07 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as aluminum detector surface of the S0001 experiment. Of the 282 impacts found, 230 were below the >0.5 mm criteria for impact craters and were not imaged. Of these, 20 were located on the experiment-tray clamps (C01-C08), 71 were located on the experiment-tray flanges, and 139 were located on the aluminum detector surfaces. Of the remaining 52 features which were photodocumented, 31 between 0.5 and 1.0 mm, six between 1.0 and 1.5 mm, one between 1.5 and 2.0 mm, and one between 2.0 mm and 2.5 mm in diameter were imaged on the aluminum experimental surfaces. Nine of the 52 impacts imaged, were located on the experiment-tray flanges, five between 0.5 mm and 1.0 mm and four between 1.0 mm and 1.5 mm in diameter. Three features, ranging in diameter from 0.5 mm to 0.9 mm, were located on experiment-tray clamps (C03 and C06), and one feature which measured ~0.6 mm in diameter was located on the side of tray-clamp bolt S04B. All features examined were typical of craters formed in aluminum under hypervelocity laboratory conditions.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	20	71	139	230
≥0.5 mm	4	9	39	52
TOTALS	24	80	178	282

The largest impact feature found on this tray measured ~2.2 mm in diameter and was located on one of the aluminum collection plates at the base of the tray.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection (February 22, 1990) was conducted while the experiment tray was mounted on the spacecraft and identified three features which might be damaged by the attachment of the experiment-tray cover and five additional features which could be damaged or destroyed by the placing of the experiment tray within the experiment-tray rotator stand. These latter were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the most interesting feature within the

experiment-tray cover area, the cover gasket was cut in one location to prevent it from coming into contact with this feature and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges or spallation features on the 0.0625" (1.6 mm) thick experiment-tray flanges or backside.

DOCUMENTATION:

Examination and photodocumentation of tray E07 and associated clamp bolts were accomplished on March 26-27, 1990 in the horizontal position utilizing M&D SIG System #3. The clamps associated with this tray were scanned with M&D SIG System #2 on March 23. The coordinates for all features were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC030001.E07	RC030001.E07	50	3		0.8	Al	*3*
LC030002.E07	RC030002.E07	107	23		0.9	Al	*d*
LC060001.E07	RC060001.E07	3	46		0.5	Al	
LS040001.E07	RS040001.E07	0	0	5	0.6	Steel	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.E07	RE000001.E07	1284	884		1.4	Al	
LE000011.E07	RE000011.E07	1105	970		0.6	Al	*x*
LE000012.E07	RE000012.E07	1075	950		1.1	Al	*x*
LE000027.E07	RE000027.E07	-20	323		0.7	Al	
LE000033.E07	RE000033.E07	650	-20		0.5	Al	
LE000045.E07	RE000045.E07	165	-30		1.1	Al	*2*
LE000046.E07	RE000046.E07	555	-40		0.5	Al	*2*
LE000047.E07	RE000047.E07	127	950	-48	1.0	Al	*4,f*
LE000048.E07	RE000048.E07	755	950		0.9	Al	*4*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000002.E07	RE000002.E07	1120	660		0.6	Al	
LE000003.E07	RE000003.E07	1125	915		0.9	Al	
LE000004.E07	RE000004.E07	1077	935		0.8	Al	
LE000005.E07	RE000005.E07	1155	805		0.6	Al	
LE000006.E07	RE000006.E07	1060	745		0.7	Al	
LE000007.E07	RE000007.E07	990	810		0.5	Al	
LE000008.E07	RE000008.E07	1020	685		0.6	Al	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000009.E07	RE000009.E07	1030	492		0.6	Al	*5*
AE000009.E07	BE000009.E07	1030	492		0.6	Al	
LE000010.E07	RE000010.E07	990	475		0.6	Al	
LE000013.E07	RE000013.E07	850	830		0.7	Al	
LE000014.E07	RE000014.E07	760	720		1.2	Al	*1,d*
LE000015.E07	RE000015.E07	795	825		1.2	Al	
LE000016.E07	RE000016.E07	700	695		0.5	Al	
LE000017.E07	RE000017.E07	575	880		1.5	Al	
LE000018.E07	RE000018.E07	560	820		0.7	Al	
LE000019.E07	RE000019.E07	600	640		0.6	Al	
LE000020.E07	RE000020.E07	365	715		0.7	Al	
LE000021.E07	RE000021.E07	140	520		0.6	Al	
LE000022.E07	RE000022.E07	70	820		0.6	Al	
LE000023.E07	RE000023.E07	18	485		0.6	Al	
LE000024.E07	RE000024.E07	58	200		1.5	Al	
LE000025.E07	RE000025.E07	155	304		1.0	Al	
LE000026.E07	RE000026.E07	268	105		1.6	Al	
LE000028.E07	RE000028.E07	335	240		0.6	Al	
LE000029.E07	RE000029.E07	379	317		0.6	Al	*6*
AE000029.E07	BE000029.E07	379	317		0.6	Al	
LE000030.E07	RE000030.E07	433	67		0.6	Al	
LE000031.E07	RE000031.E07	537	302		0.6	Al	
LE000032.E07	RE000032.E07	577	194		0.5	Al	*d*
LE000034.E07	RE000034.E07	670	125		0.5	Al	
LE000035.E07	RE000035.E07	655	220		0.7	Al	
LE000036.E07	RE000036.E07	683	384		1.0	Al	
LE000037.E07	RE000037.E07	846	109		0.7	Al	
LE000038.E07	RE000038.E07	843	234		2.2	Al	
AE000038.E07	BE000038.E07	843	234		2.2	Al	
LE000039.E07	RE000039.E07	877	289		0.8	Al	
LE000040.E07	RE000040.E07	945	32		0.9	Al	
LE000041.E07	RE000041.E07	1082	404		0.9	Al	
LE000042.E07	RE000042.E07	1150	65		0.6	Al	
LE000043.E07	RE000043.E07	1210	79		0.8	Al	
LE000044.E07	RE000044.E07	1205	289		0.7	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Ejecta is red.
2 - Image taken at 13° from normal to crater.
3 - Impact into black paint edging around white paint sample.
4 - Image taken at 45° from normal to crater.
5 - Image blurred due to camera vibration.
6 - Image of feature #28 instead of feature #29.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-82-32
Pre-Deintegration - KSC-390C-1032.08, KSC-390C-1032.10, KSC-390C-1032.03
Post Deintegration - KSC-390C-2287.02, KSC-390C-2287.04
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - E07C02, E07C03, E07C05, and E07C07
Clamp Bolt - E07S04B

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION: E08
EXPERIMENT IDENTIFICATION: A0187-2
EXPERIMENT TITLE: CHEMICAL AND ISOTOPIC MEASUREMENT OF MICROMETEOROIDS BY SECONDARY ION MASS SPECTROMETRY
PRINCIPAL INVESTIGATOR: E. ZINNER
WASHINGTON UNIVERSITY, ST. LOUIS
ST. LOUIS, MISSOURI 63130

SUMMARY OF OBSERVATIONS

The entire surface of this 3"-deep (7.6 cm) experiment tray occupying Bay E08 was covered with the passive A0187-2 micrometeoroid collector. This experiment consisted of 120 capture cells, each composed of four 38 x 42 mm, 0.5 mm thick germanium crystal wafers which were bonded with 1 mm thick strips of silicone RTV to an 86 x 94 mm, 3 mm thick 6061-T6 aluminum backplate and covered with 2 μm thick metallized (200 Å Au/Pd exterior, 1000 Å Ta interior) mylar foils. There were two additional trays on LDEF with A0187-2 germanium capture cells at locations A02 and E03. The meteoroid capture cells were attached to six 0.25" (6.4 mm) thick, 6061-T6 aluminum mounting plates which were screwed (stainless steel) to an underlying frame. The six sets of capture cells were separated by ~1" (~2.5 cm) exposing the underlying aluminum mounting plate.

None of the 120 mylar foils were still intact when LDEF was retrieved from low-Earth orbit. This compares to one out of 40 and 11 out of 77 for trays A02 and E03, respectively. The broken foils were still attached to the capture-cell frames in many places, the majority of which had rolled up into coils which looked like shards and projected at all angles away from the surface. Some of this material came off during the LDEF rotation operations, contaminating other surfaces. The front of the imaging M&D SIG microscope had to be wiped down with anti-static pads to avoid attracting the mylar shards.

Impacts into germanium were typical of crystalline material impacts. See Section 2.B. for a detailed description of this phenomenon. In short, there were generally frontside spall zones (included in imaged areas) associated with most features, as well as extended fracture zones surrounding many of the larger features, some extending across the entire germanium surface. Nineteen impacts totally penetrated the germanium wafers. Penetration hole diameters are listed in the table below with appropriate comments; all other diameter values listed refer to crater rim measurements. Impacts which are believed to have occurred when the mylar foils were still intact had associated debris rings surrounding the feature on the germanium-wafer surface. Because this experimental surface was designed to disrupt incoming hypervelocity particles, the number and size of impact features should not be comparable to those observed on other surfaces with equivalent positions on LDEF. Furthermore, the uncovered germanium surfaces were contaminated with bits of the broken mylar foils and particles of the metal coatings from the foils. This made it extremely difficult to count small features, and some contamination features which were not actual impacts may have been counted as small features.

The M&D SIG survey identified a total of 1112 features on all surfaces associated with tray E08. Twenty seven features <0.5 mm, and one >0.5 mm in diameter, were found on the various 0.19" (4.8 mm) thick, chromic anodized 6061-T6 aluminum tray clamps. One small feature was found on the side of a stainless-steel washer on bolt C04A. Twenty four features with diameters <0.5 mm, and three with diameters >0.5 mm were found on the experiment-tray flanges. Ten features with diameters >0.5 mm, including two with diameters between 1.0-1.5 mm, were found on aluminum surfaces within the experimental surface area. Twenty four features with diameters >0.5 mm were found on the various germanium surfaces, 19 of which penetrated the germanium wafers, including four which produced holes between 1.0 and 1.5 mm in diameter and one which

produced a 1.6 mm diameter hole. The remaining 1020 features were all <0.5 mm in diameter and were located on the experiment surfaces.

A total of 50 features were imaged, including the one large feature on a tray clamp, the three large features on the experiment-tray flanges, the 34 large features on the experimental surfaces, and 12 features on germanium surfaces which were <0.5mm but were representative of features in this size range, or had interesting associated debris patterns or spall zones This last category included one representative feature (LE000007.E08) which consisted of a high-density crater field which was apparently caused by a disrupted impactor which struck the germanium surface after passing through the intact mylar foil.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	28	24	1022	1074
>0.5 mm	1	3	34	38
TOTALS	29	27	1056	1112

The largest feature on tray E08 was an ~1.6 mm penetration hole in a germanium plate (LE000011.E08). There were several other impacts which penetrated the germanium plates and had extensive associated spall- and fracture zones as described above.

M&D SIG INSPECTIONS

PRE-DEINTEGRATION:

Five features were found on the tray clamps and 27 on the experiment-tray flanges during the visual inspection of tray E08 (February 22, 1990) while it was still mounted on LDEF. Two features which were >0.5 mm in diameter were on the experiment-tray flanges in areas which could have been subjected to contact by the experiment-tray cover gasket, and corresponding strips of gasket material were removed prior to attaching the cover to the tray. No significant features were in areas which would have been contacted by the tools, but eight features <0.3 mm in diameter were in areas which would have been contacted by the experiment-tray rotator stand clamping mechanism. These latter features were not examined or photodocumented, nor were they included in the numerical summary given above.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick, chromic-anodized, 6061-T6 experiment-tray flanges.

DOCUMENTATION:

Tray E08 was inspected and photodocumented on March 9, 1990 using imaging M&D SIG System #1 and Coordinate Registration System #2. Tray clamps, bolts, and shims were also inspected and imaged on March 9 using M&D SIG System #3. The bottom left and top right corners of each of the six mounting plates holding the meteoroid capture cells were marked with a dot of black ink and the X,Y-coordinates were recorded for reference and are listed below. The plates themselves were assigned numbers 1-6 from left to right, top to bottom.

Bolt-Hole Registration - Not Determined

A0178-2 Fiducial Mark Locations (mm)

PLATE	TOP X	TOP Y	BOTTOM X	BOTTOM Y
1	417	947	6	488
2	834	946	426	488
3	1254	949	847	488
4	415	472	2	9
5	831	473	424	10
6	1251	471	841	11

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC070001.E08	RC070001.E08	58	38		0.8	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.E08	RE000001.E08	287	982		0.5	Al	*k*
LE000048.E08	RE000048.E08	1192	-14		0.7	Al	
LE000049.E08	RE000049.E08	725	-6		0.6	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000002.E08	RE000002.E08	143	982		0.4	Ge	*b*
LE000003.E08	RE000003.E08	329	926		0.4	Ge	*b*
LE000004.E08	RE000004.E08	337	876		0.3	Ge	*b*
LE000005.E08	RE000005.E08	338	828		0.4	Ge	*b*
LE000006.E08	RE000006.E08	184	836		0.6	Ge	*b,d*
LE000007.E08	RE000007.E08	155	804		ND	Ge	*4,d*
LE000008.E08	RE000008.E08	720	869		0.4	Ge	*b,d*
LE000009.E08	RE000009.E08	543	795		0.9	Ge	*1,b*
LE000010.E08	RE000010.E08	655	824		1.4	Ge	*1,b,m*
LE000011.E08	RE000011.E08	699	744		1.6	Ge	*1,b,m*
LE000012.E08	RE000012.E08	856	888		0.6	Al	
LE000013.E08	RE000013.E08	1061	938		0.8	Al	
LE000014.E08	RE000014.E08	1036	895		0.6	Ge	*1,b,m*
LE000015.E08	RE000015.E08	1230	905		0.4	Ge	
LE000016.E08	RE000016.E08	1004	764		1.2	Al	*d,e*
LE000017.E08	RE000017.E08	1028	698		0.3	Ge	*b,d*
LE000018.E08	RE000018.E08	267	602		0.6	Ge	*1,2,b*
LE000019.E08	RE000019.E08	217	621		0.6	Ge	*b*
LE000020.E08	RE000020.E08	378	587		0.8	Ge	*b*
LE000021.E08	RE000021.E08	385	658		0.7	Ge	*1,b,d*
LE000022.E08	RE000022.E08	399	627		0.8 x 0.9	Al	
LE000023.E08	RE000023.E08	393	486		0.6	Al	
LE000024.E08	RE000024.E08	109	545		0.9	Ge	*1,b,m*
LE000025.E08	RE000025.E08	397	262		1.1	Al	*e*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000026.E08	RE000026.E08	330	206		0.5	Ge	*1,b*
LE000027.E08	RE000027.E08	382	214		1.3	Ge	*1,b*
LE000028.E08	RE000028.E08	605	487		0.6	Al	
LE000029.E08	RE000029.E08	504	618		0.5 x 0.6	Ge	*b*
LE000030.E08	RE000030.E08	509	514		0.5	Ge	*1,b*
LE000031.E08	RE000031.E08	608	507		0.6	Ge	*1,b*
LE000032.E08	RE000032.E08	660	532		0.9	Ge	*1,b*
LE000033.E08	RE000033.E08	758	545		0.5	Ge	*1,b*
LE000034.E08	RE000034.E08	884	645		0.5	Ge	*1,b*
LE000035.E08	RE000035.E08	423	206		0.7	Al	
LE000036.E08	RE000036.E08	828	384		0.6	Al	
LE000037.E08	RE000037.E08	595	216		1.3	Ge	*1,b*
LE000038.E08	RE000038.E08	602	222		0.4	Ge	*1,b*
LE000039.E08	RE000039.E08	691	214		0.6	Ge	
LE000040.E08	RE000040.E08	843	339		0.6	Al	
LE000041.E08	RE000041.E08	968	377		0.9	Ge	*1,b*
LE000042.E08	RE000042.E08	29	149		1.0	Ge	*1,3,b,m*
LE000043.E08	RE000043.E08	166	126		0.7	Ge	*1,b,m*
LE000044.E08	RE000044.E08	243	127		0.3	Ge	*b,d*
LE000045.E08	RE000045.E08	42	30		0.4	Ge	*b,d*
LE000046.E08	RE000046.E08	1015	160		0.6	Ge	*b,k*
LE000047.E08	RE000047.E08	1097	38		0.3	Ge	*b,d*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Projectile penetrated the germanium wafer.
2 - Wrong coordinates (X = 217, Y = 621) input into image file.
3 - Impact chipped off a piece of the germanium wafer from one edge.
4 - Image of a high-density cluster of small features.

OTHER PHOTODOCUMENTATION:

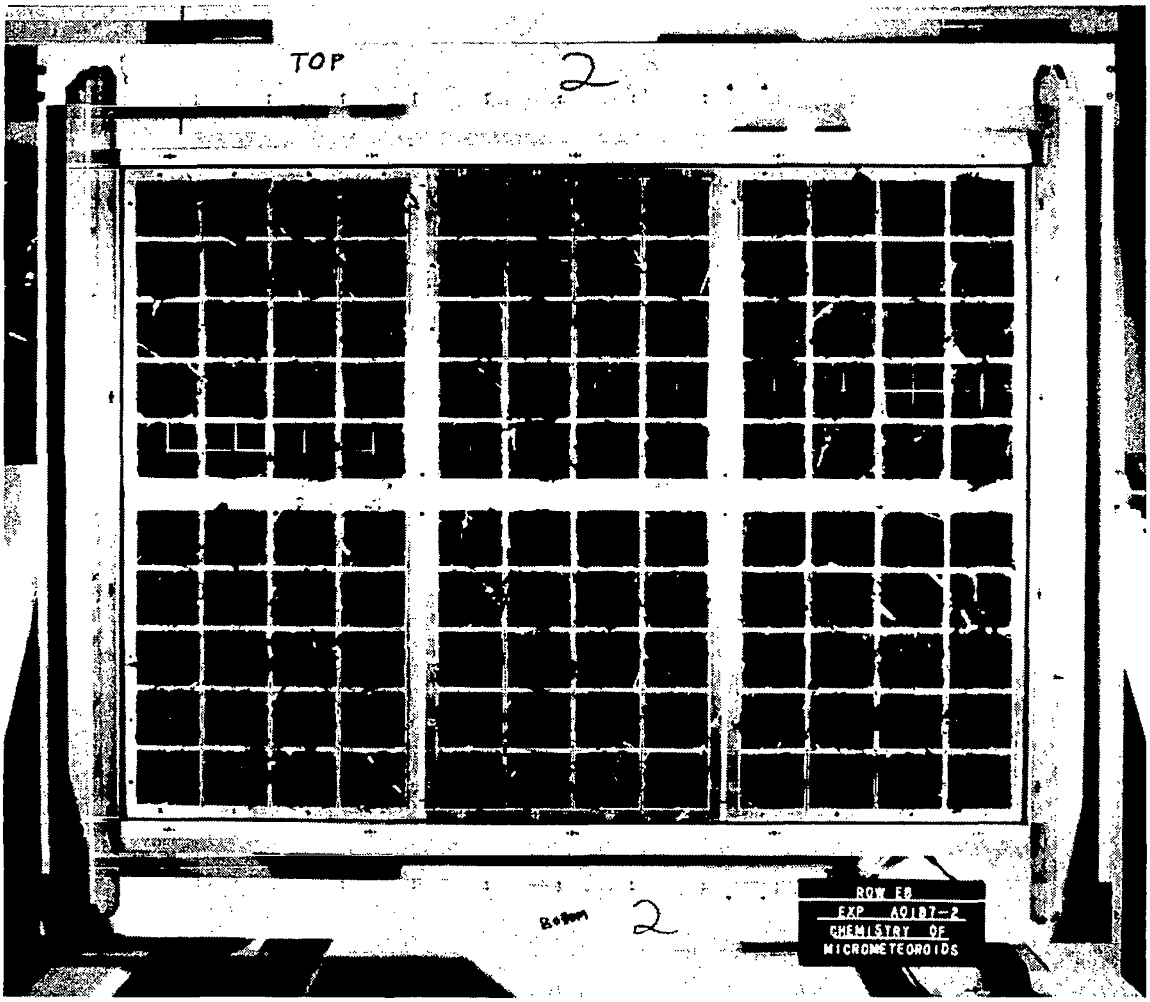
Pre-Flight - 84-07045
On-Orbit - S32-76-16
Pre-Deintegration - KSC-390C-1031.03, KSC-390C-1031.05, KSC-390C-1031.08
Post Deintegration - KSC-390C-1767.02
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - E08C02, E08C04, E08C05, and E08C07
Clamp Bolts - E08S04A

ACCOMPANYING FIGURES:

Figure E08-1. This post-deintegration view shows the front of the entire E08 experiment tray.


TOP
2
Bottom
2
ROW E8
EXP A0187-2
CHEMISTRY OF
MICROMETEOROIDS

LDEF LOCATION: E09
EXPERIMENT IDENTIFICATION: S0014
EXPERIMENT TITLE: ADVANCED PHOTOVOLTAIC EXPERIMENT
PRINCIPAL INVESTIGATOR: D. BRINKER
302-1 NASA LEWIS RESEARCH CENTER
CLEVELAND, OHIO 44135

SUMMARY OF OBSERVATIONS

Bay E09 is an active experiment tray which contained experiment S0014, the Advanced Photovoltaic Experiment. Experiment S0014 is a combination of three photovoltaics-related experiments to measure the solar spectrum and the effects of space exposure on photovoltaics. The experiment occupied this 12"-deep (30.5 cm) peripheral tray, and used $LiSO_2$ batteries to run its Experiment Power and Data System (EPDS) for data collection.

The S0014 experiment hardware consists of numerous silicon and gallium arsenide solar cells, solar cell covers, and solar cell modules and assemblies. The experiment also contained a series of optical bandpass filters, with multiple layers of materials such as aluminum, magnesium fluoride, silicon dioxide, silver, thorium fluoride, zinc sulfide, lead fluoride, and cryolite. Optical materials and substrates were a variety of fused silica, Corning, and Schott glasses. An absolute radiometer detector was also housed in this experiment. The experiment samples were mounted under a slotted, black anodized, 6061-T6 aluminum frame (probably 0.0625" [~1.6 mm] thick). This was intended to limit the field of view of the solar cells and other hardware. One small (~2" [~5.1 cm] square) piece of aluminum fell out of this tray, from the area of the solar concentrators, during rotation of LDEF for deintegration. This aluminum square was recovered and surveyed, and was assigned the component identification of "E01".

Bay E09 showed two primary types of impact morphology. The impacts into crystalline specimens, like glass, created deep well-like craters in the center of the impact features with a surrounding outer spallation region, usually surrounded by a fracture zone, and sometimes accompanied by substrate fracture. Impacts into metals were typical of craters produced during laboratory hypervelocity impact tests.

On experiment tray E09, the M&D SIG survey visually identified a total of 689 impact features on all associated experiment-tray surfaces. These surfaces included the tray flanges and walls (0.125" [3.2 mm] thick chromic anodized 6061-T6 aluminum), the experiment-tray clamps (0.19" [4.8 mm] thick chromic anodized 6061-T6 aluminum), and the experiment-tray clamp bolts (303 stainless steel). On the experiment surfaces, 580 impacts were located. Of these, 537 were <0.5 mm in diameter (ten were photodocumented as they were considered to be of interest, three of which were located on the recovered aluminum square), 29 were between 0.5 mm and 1.0 mm in diameter, seven were between 1.0 mm and 1.5 mm in diameter, and three were between 1.5 mm and 2.0 mm in diameter. Of the 42 impacts on the experiment-tray flanges and walls, 32 were <0.5 mm in diameter and were not photodocumented, nine were between 0.5 mm and 1.0 mm in diameter, and one was between 1.0 mm and 1.5 mm in diameter. On the experiment-tray clamps, all of the 67 impacts identified were <0.5 mm in diameter and were not photodocumented.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	67	32	537	636
>0.5 mm		10	43	53
TOTALS	67	42	580	689

The largest impact features identified were (1) an ~1.8 mm diameter crater located on a solar cell, (2) an ~1.4 mm diameter crater in the experiment-tray flanges, and (3) an ~0.4 mm crater on an experiment-tray

clamp. A total of 58 features were photodocumented from tray E09. Five features could not be documented due to their locations. The Principal Investigator expressed his willingness to provide the slotted aluminum frame to the M&D SIG for further analysis. Of particular interest is an ~1.4 mm diameter impact penetration through the inner wall of this frame. This penetration sprayed ejecta along the adjacent bolt covers and inner walls.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment tray was mounted on the spacecraft. This inspection identified fourteen features which might be destroyed by attachment of the experiment-tray cover and four features which would be destroyed by emplacement in the experiment-tray rotator. These latter impact features were estimated to be ~0.5 mm in diameter. These features were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in five locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges. One feature each was identified on clamps C06 and C08, two were identified on clamp C03, and three were identified on clamp C02.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations or spallation features on the front or back of the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

The detailed examination and photodocumentation of tray E09 was conducted on March 12 and 13, 1990 in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #2. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale. The recovered aluminum square was scanned using M&D SIG System #1, and the coordinates for features were measured with a metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	60	946	55	-28
Center	617	948	614	-26
Far Right	1175	950	1170	-25

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.E09	RE000001.E09	0	732		0.7	Al	*1*
LE000002.E09	RE000002.E09	190	953		0.6	Al	
LE000003.E09	RE000003.E09	1119	944		0.5	Al	
LE000004.E09	RE000004.E09	1255	783		0.5	Al	
LE000005.E09	RE000005.E09	1250	767		0.5	Al	
LE000039.E09	RE000039.E09	-7	90		0.8	Al	
LE000040.E09	RE000040.E09	-15	55		0.6	Al	
LE000041.E09	RE000041.E09	99	-45		1.4	Al	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	COMMENTS
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	
LE000042.E09	RE000042.E09	213	-28		0.7	Al	
LE000043.E09	RE000043.E09	1113	-22		0.5	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	COMMENTS
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	
LE000006.E09	RE000006.E09	115	878		0.6	Al	
LE000007.E09	RE000007.E09	397	921		0.9	Al	
LE000008.E09	RE000008.E09	119	847		0.6	Al	
LE000009.E09	RE000009.E09	402	786		1.1	Al	
LE000010.E09	RE000010.E09	434	671		1.1	Al	
LE000011.E09	RE000011.E09	657	904		0.9	Al	
LE000012.E09	RE000012.E09	571	690		0.8	Al	
LE000013.E09	RE000013.E09	1077	869		0.4, 0.9	Al	*2,b*
LE000014.E09	RE000014.E09	57	835	100	0.8	SC	*3,*
LE000015.E09	RE000015.E09	256	754	100	0.5, 2.1	SC (NB 30)	*2,b*
LE000016.E09	RE000016.E09	1100	716	100	0.6, 0.7	Al	*4*
LE000017.E09	RE000017.E09	483	653	212	0.4, 2.2	SC (NF 4)	*5*
LE000018.E09	RE000018.E09	700	580	260	0.3, 0.8	SC (M 10)	*5,6*
LE000019.E09	RE000019.E09	738	472	260	0.3, 0.9	SC (M 9)	*2,7,b,m*
LE000020.E09	RE000020.E09	619	501	212	0.1, 2.1	SC (M 3)	*8,m*
LE000021.E09	RE000021.E09	446	475	212	0.7	Al	*3*
LE000022.E09	RE000022.E09	490	300	212	0.8	Al	
LE000023.E09	RE000023.E09	250	247	100	1.8, 0.3	SC (NB 9)	*9*
AE000023.E09	BE000023.E09	250	247	100	1.8, 0.3	SC (NB 9)	*9*
LE000024.E09	RE000024.E09	875	643	100	0.7, 3.0	Glass (H12)	*2,b*
LE000025.E09	RE000025.E09	681	395	40	1.1, 3.0	Al	*2,10,12,b,e*
AE000025.E09	BE000025.E09	681	395	40	1.4, 2.6	Al	*2,10,11,b,e*
LE000026.E09	RE000026.E09	194	301		1.1	Al	
LE000027.E09	RE000027.E09	300	438		0.9, 0.4	Al	*4*
LE000028.E09	RE000028.E09	290	651		0.8, 1.0	Al	*2,b*
LE000029.E09	RE000029.E09	408	330		0.6, 0.9	Al	*2,b*
LE000030.E09	RE000030.E09	851	323		0.8	Al	
LE000031.E09	RE000031.E09	908	311		0.9	Al	
LE000032.E09	RE000032.E09	913	282		0.6, 1.0	Al	*2,b*
LE000033.E09	RE000033.E09	1068	288		0.6	Al	
LE000034.E09	RE000034.E09	1030	424		0.6	Al	
LE000035.E09	RE000035.E09	1027	638		1.1, 1.6	Al	*2,b*
LE000036.E09	RE000036.E09	1060	505		0.8, 1.5	Al	*2,b*
LE000037.E09	RE000037.E09	1146	434		1.5	Al	
LE000038.E09	RE000038.E09	1146	301		1.1, 1.5	Al	*2,b*
AE000038.E09	BE000038.E09	1146	301		1.1, 1.5	Al	*2,b*
LE000044.E09	RE000044.E09	55	6		0.7, 1.1	Al	*2,b*
LE000045.E09	RE000045.E09	282	238		0.8, 1.3	Al	*2,b*
LE000046.E09	RE000046.E09	282	253		0.6, 0.9	Al	*2,b*
LE000047.E09	RE000047.E09	366	36		0.7	Al	*13*
LE000048.E09	RE000048.E09	727	41		0.7	Al	
LE000049.E09	RE000049.E09	930	93		0.8, 1.2	Al	*2,b*
LE000050.E09	RE000050.E09	1009	223		0.1, 2.4	Glass	*5,14*
LE000051.E09	RE000051.E09	448	124	212	1.5	Al	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000052.E09	RE000052.E09	333	149	100	0.6	Al	
LE000053.E09	RE000053.E09	324	132	100	0.6	Al	
LE000054.E09	RE000054.E09	344	223	100	0.5, 2.3	SC (NA 9)	*2,b*
LE000055.E09	RE000055.E09	172	116	100	0.7	Al	
LE000056.E09	RE000056.E09	1116	148	65	1.8 x 4.3	Al	*15,d*
LE010001.E09	RE010001.E09	31	20		0.2	Al	
LE010002.E09	RE010002.E09	50	59		0.1	Al	
LE010003.E09	RE010003.E09	58	26		0.1	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

SC - Solar Cell (Principal Investigator's identification number in parenthesis)

1 - Wrong coordinates (X = 0, Y = 90) input into image file.
2 - Diameter after comma is diameter of spallation zone.
3 - Image taken at 15° from normal to crater.
4 - Two craters in image; the two diameters are given separated by comma.
5 - Diameter after comma is diameter of melt zone in cover glass.
6 - Wrong coordinates (X = 738, Y = 472) input into image file.
7 - Impact penetrated cover glass (diameter given) and cratered silicon solar cell (crater diameter = 0.1 mm); two long cracks in cover glass.
8 - Diameter after comma is diameter of fracture zone in cover glass.
9 - First diameter is diameter of crater in cover glass; second diameter is diameter of crater in aluminum.
10 - First diameter given is hole diameter; impact penetrated wall of black anodized aluminum frame covering samples.
11 - Image taken at 45° above normal to crater.
12 - Backside view of penetration hole and ejecta spray pattern; image taken at 45° above and 30° right of normal to crater.
13 - Crater lip was broken off.
14 - Impact into digital solar aspect sensor.
15 - Ejecta debris spray only; on aluminum X-beam of aluminum frame; aluminum foils are loose.

OTHER PHOTODOCUMENTATION:

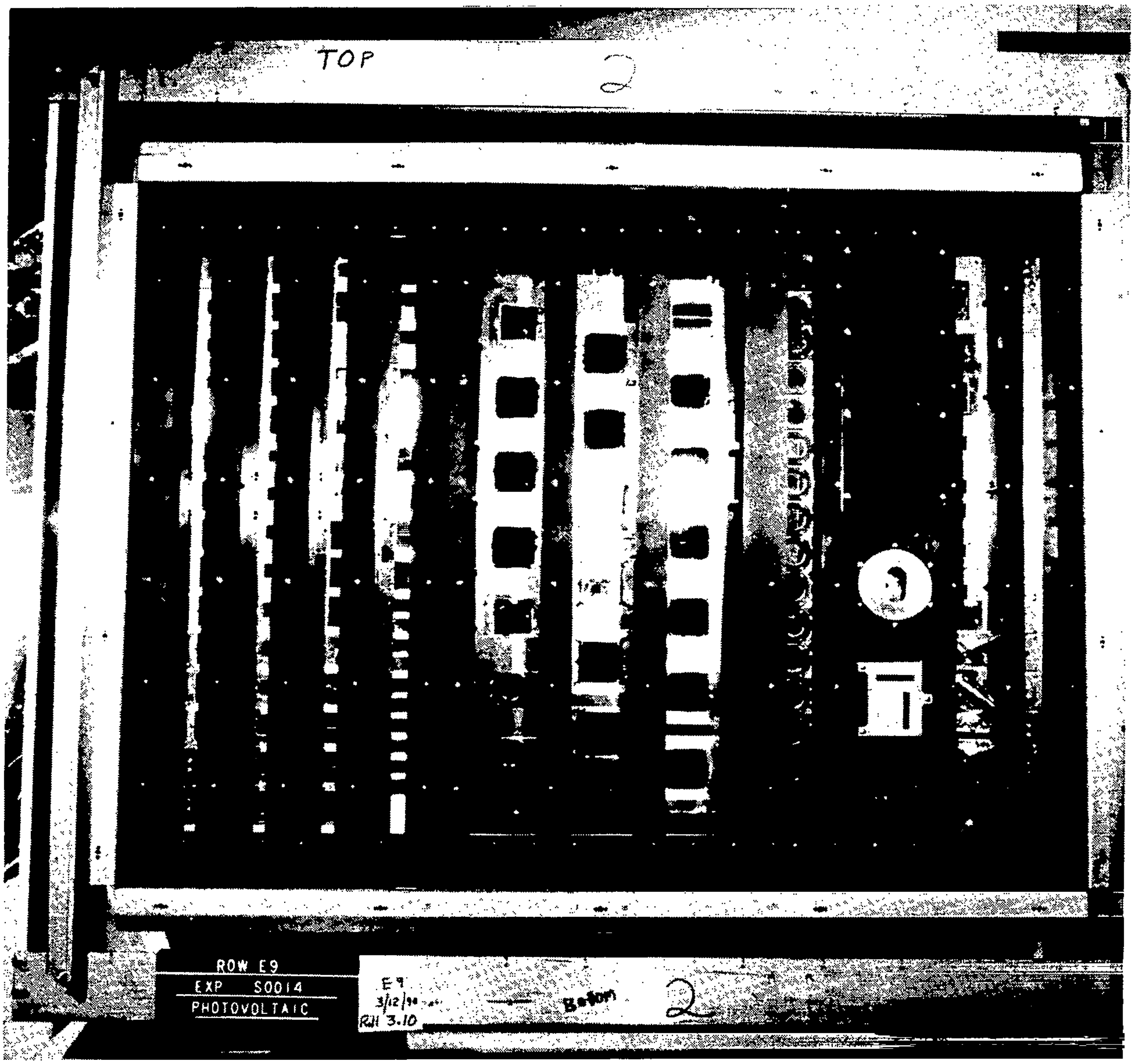
Pre-Flight - 108-KSC-384C-193/1 through 108-KSC-384C-193/3
On-Orbit - S32-78-090
Pre-Deintegration - KSC-390C-1030.07, KSC-390C-1030.12, KSC-390C-1031.02
Post Deintegration - KSC-390C-1814.10
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - E09C01, E09C05, E09C07, and E09C08
Clamp Bolts - E09S05C and E09S07C

ACCOMPANYING FIGURES:

Figure E09-1. This post-deintegration view shows the front of the entire E09 experiment tray.


TOP
2
ROW E9
EXP S0014
PHOTOVOLTAIC
E9
2

LDEF LOCATION: E10
EXPERIMENT IDENTIFICATION: A0178
EXPERIMENT TITLE: A HIGH RESOLUTION STUDY OF ULTRA-HEAVY COSMIC-RAY NUCLEI
PRINCIPAL INVESTIGATOR: D. O'SULLIVAN
DUBLIN INSTITUTE FOR ADVANCED STUDIES
DUBLIN, IRELAND

SUMMARY OF OBSERVATIONS

Bay E10 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46"-long (116.8 cm), 10" (25.4 cm) diameter aluminum cylinders which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with a ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (facing space) of FEP Teflon (~120 μm thick) backed with a thin layer of silver-inconel (~200 to 300 Å thick), which in turn is backed by Chemglaze Z306 black conductive paint and binding medium (~80 to 100 μm thick). The structure and attachments for the experiment tray consisted of the tray flanges and walls (0.125" [3.2 mm] thick chromic anodized 6061-T6 aluminum), the experiment-tray clamps (0.19" [4.8 mm] thick chromic anodized 6061-T6 aluminum), and the experiment-tray clamp bolts (303 stainless steel). The backs of the trays were also covered with a reflective thermal blanket.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted Teflon material. Commonly, the Teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. When impacts occurred into the velcro which supported the thermal blanket materials, large delamination areas were very common around the penetration. Many penetrations possessed several sharp, distinct, colored rings, while others exhibited a more continuous halo phenomenon where the change from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impacts into aluminum.

The M&D SIG survey visually identified a total of 570 impact features on the E10 experiment tray, including the experiment-tray clamps and flanges, as well as the thermal insulation blanket. Of these, 397 were found on the thermal blanket, all but a few representing penetrations through the blanket. Two hundred seventy six features from the blanket were below the 0.3 mm diameter photodocumentation threshold, 119 features were between 0.3 mm and 1.0 mm in diameter, and two features were photodocumented which were between 1.0 mm and 1.5 mm in diameter. One hundred twenty eight features were found on the tray flanges, 112 of which were <0.5 mm in diameter, 13 of which were between 0.5 mm and 1.0 mm in diameter, one of which was between 1.0 mm and 1.5 mm in diameter, and two of which were between 1.5 mm and 2.0 mm in diameter. The remaining 45 features were located while scanning the associated bolts, clamps, and shims for tray E10.

Thirty eight of these features were <0.5 mm in diameter and were not photodocumented, five were between 0.5 mm and 1.0 mm in diameter, and two were between 1.0 mm and 1.5 mm in diameter.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			276	276
>0.3 mm			121	121
<0.5 mm	38	112		150
>0.5 mm	7	16		23
TOTALS	45	128	397	570

The largest impact features identified were (1) an ~1.1 mm penetration hole through the thermal blanket, (2) an ~3.2 mm diameter delamination zone around an ~0.9 mm diameter penetration into a velcro support for the thermal blanket, (3) an ~1.8 mm diameter crater in the experiment-tray flanges, and (4) an ~1.2 mm crater on an experiment-tray clamp. A total of 144 features were photodocumented from tray E10.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment tray was mounted on the spacecraft. This inspection identified eight features which might be destroyed by attachment of the experiment-tray cover. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges. One feature was identified on clamp C08, and two features were identified on clamp C07.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

The detailed examination and photodocumentation of Tray E10 was conducted on March 23 and 26, 1990 in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #2. The clamps associated with this tray were scanned and imaged with M&D SIG System #2; the coordinates for features residing on the clamps were measured with a metric scale. The bolts and shims associated with this tray were scanned with M&D SIG System #3.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	57	948	51	-26
Center	615	950	609	-25
Far Right	1174	951	1166	-23

Fiducial Mark Locations (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	237	900	230	21
Center	620	898	592	23
Far Right	1011	900	890	23

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC010001.E10	RC010001.E10	53	44		1.2	Al	
LC030001.E10	RC030001.E10	110	46		0.6	Al	
LC040001.E10	RC040001.E10	40	17		0.6	Al	
LC050001.E10	RC050001.E10	77	12		0.8	Al	
LC070001.E10	RC070001.E10	45	22		0.5	Al	
LC070002.E10	RC070002.E10	90	16		1.1	Al	
LC080001.E10	RC080001.E10	76	27		0.7	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.E10	RE000001.E10	505	958		0.7	Al	
LE000002.E10	RE000002.E10	522	946		0.6	Al	
LE000003.E10	RE000003.E10	656	937		0.4 x 0.7	Al	
LE000004.E10	RE000004.E10	1258	885		0.6	Al	
LE000096.E10	RE000096.E10	-4	242		0.7	Al	
LE000097.E10	RE000097.E10	-10	338		0.5	Al	*1*
LE000098.E10	RE000098.E10	-17	595		0.5	Al	*1*
LE000099.E10	RE000099.E10	-13	636		0.8	Al	*1*
LE000100.E10	RE000100.E10	-8	108		0.8	Al	*1*
LE000101.E10	RE000101.E10	163	-20		1.0	Al	*2*
LE000102.E10	RE000102.E10	177	-55		1.6	Al	*k*
LE000103.E10	RE000103.E10	695	-26		1.8	Al	
LE000104.E10	RE000104.E10	709	-13		0.5	Al	
LE000105.E10	RE000105.E10	924	-31		0.8	Al	
LE000106.E10	RE000106.E10	1089	-45		0.7	Al	
LE000107.E10	RE000107.E10	1176	-10		0.7	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000005.E10	RE000005.E10	54	797		0.7	TB	
LE000006.E10	RE000006.E10	142	856		0.5	TB	
LE000007.E10	RE000007.E10	150	871		0.6	TB	
LE000008.E10	RE000008.E10	176	824		0.3	TB	
LE000009.E10	RE000009.E10	250	849		0.4	TB	
LE000010.E10	RE000010.E10	313	868		0.3	TB	
LE000011.E10	RE000011.E10	336	861		0.5	TB	
LE000012.E10	RE000012.E10	452	898		0.5	TB	
LE000013.E10	RE000013.E10	511	860		0.4	TB	
LE000014.E10	RE000014.E10	563	807		0.4	TB	*3*
LE000015.E10	RE000015.E10	530	816		0.7	TB	*4*
LE000016.E10	RE000016.E10	574	871		0.4	TB	*5*
LE000017.E10	RE000017.E10	585	894		0.4	TB	
LE000018.E10	RE000018.E10	593	861		0.4	TB	*5*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000019.E10	RE000019.E10	612	822		0.4	TB	
LE000020.E10	RE000020.E10	716	894		0.7 x 1.3	TB	
LE000021.E10	RE000021.E10	735	813		0.5	TB	*6*
LE000022.E10	RE000022.E10	747	799		0.5	TB	*7*
LE000023.E10	RE000023.E10	746	917		0.5	TB	*8*
LE000024.E10	RE000024.E10	772	858		0.6	TB	
LE000025.E10	RE000025.E10	804	907		0.5	TB	
LE000026.E10	RE000026.E10	890	801		0.4	TB	
LE000027.E10	RE000027.E10	943	789		0.4	TB	
LE000028.E10	RE000028.E10	981	734		0.6	TB	
LE000029.E10	RE000029.E10	1027	905		0.4	TB	
LE000030.E10	RE000030.E10	1204	875		0.6	TB	
LE000031.E10	RE000031.E10	35	717		0.5	TB	
LE000032.E10	RE000032.E10	19	653		0.4	TB	*1*
LE000033.E10	RE000033.E10	64	660		0.5	TB	
LE000034.E10	RE000034.E10	133	704		0.5	TB	
LE000035.E10	RE000035.E10	131	619		0.3	TB	
LE000036.E10	RE000036.E10	248	750		0.4	TB	
LE000037.E10	RE000037.E10	284	649		0.3	TB	
LE000038.E10	RE000038.E10	336	706		0.4	TB	
LE000039.E10	RE000039.E10	486	693		0.4	TB	
LE000040.E10	RE000040.E10	539	642		0.4	TB	
LE000041.E10	RE000041.E10	632	607		0.5	TB	*9*
LE000042.E10	RE000042.E10	647	676		0.6	TB	
LE000043.E10	RE000043.E10	681	644		0.4	TB	*5*
LE000044.E10	RE000044.E10	762	644		0.4	TB	
LE000045.E10	RE000045.E10	754	606		0.7	TB	*9,10*
AE000045.E10	BE000045.E10	754	606		0.7	TB	*9*
LE000046.E10	RE000046.E10	882	682		0.3	TB	
LE000047.E10	RE000047.E10	911	657		0.4	TB	
LE000048.E10	RE000048.E10	923	659		0.3	TB	
LE000049.E10	RE000049.E10	930	623		0.4	TB	
LE000050.E10	RE000050.E10	991	660		0.4	TB	
LE000051.E10	RE000051.E10	1058	631		0.4	TB	
LE000052.E10	RE000052.E10	1111	538		0.3	TB	
LE000053.E10	RE000053.E10	1133	606		0.5	TB	*9,11*
LE000054.E10	RE000054.E10	1197	491		0.4	TB	
LE000055.E10	RE000055.E10	1169	425		0.4	TB	
LE000056.E10	RE000056.E10	1144	342		0.5	TB	
LE000057.E10	RE000057.E10	1217	233		0.5	TB	
LE000058.E10	RE000058.E10	1205	218		0.4	TB	
LE000059.E10	RE000059.E10	1112	470		0.6	TB	
LE000060.E10	RE000060.E10	996	244		0.3	TB	
LE000061.E10	RE000061.E10	957	309		0.5	TB	
LE000062.E10	RE000062.E10	954	333		0.5	TB	
LE000063.E10	RE000063.E10	968	474		1.0	TB	
LE000064.E10	RE000064.E10	898	512		0.4	TB	
LE000065.E10	RE000065.E10	911	450		0.4	TB	
LE000066.E10	RE000066.E10	863	307		0.3 x 0.7	TB	*9*
LE000067.E10	RE000067.E10	813	374		0.5	TB	*9*
LE000068.E10	RE000068.E10	782	230		0.4	TB	
LE000069.E10	RE000069.E10	706	441		0.4	TB	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000070.E10	RE000070.E10	624	562		0.8	TB	
LE000071.E10	RE000071.E10	577	250		0.4	TB	
LE000072.E10	RE000072.E10	578	304		0.3	TB	
LE000073.E10	RE000073.E10	497	518		0.7	TB	
LE000074.E10	RE000074.E10	510	512		0.6	TB	
LE000075.E10	RE000075.E10	530	428		0.7	TB	
LE000076.E10	RE000076.E10	532	390		0.4	TB	
LE000077.E10	RE000077.E10	486	210		0.4	TB	
LE000078.E10	RE000078.E10	474	299		0.5, 0.3	TB	*12*
LE000079.E10	RE000079.E10	474	299		0.5, 0.3	TB	*12,13*
LE000080.E10	RE000080.E10	445	398		0.3	TB	
LE000081.E10	RE000081.E10	385	293		0.6, 0.3	TB	*10,12*
AE000081.E10	BE000081.E10	385	293		0.6, 0.3	TB	*12*
LE000082.E10	RE000082.E10	399	479		0.7	TB	
LE000083.E10	RE000083.E10	338	630		0.3	TB	
LE000084.E10	RE000084.E10	302	519		0.7	TB	
LE000085.E10	RE000085.E10	252	237		0.5 x 0.7	TB	
LE000086.E10	RE000086.E10	245	268		0.5	TB	
LE000087.E10	RE000087.E10	232	495		0.6	TB	*5*
LE000088.E10	RE000088.E10	208	565		0.4	TB	
LE000089.E10	RE000089.E10	186	299		0.6	TB	
LE000090.E10	RE000090.E10	123	378		0.3	TB	
LE000091.E10	RE000091.E10	128	476		0.7	TB	*5*
LE000092.E10	RE000092.E10	55	583		0.7	TB	
LE000093.E10	RE000093.E10	49	504		0.5	TB	
LE000094.E10	RE000094.E10	37	390		0.5	TB	
LE000095.E10	RE000095.E10	46	376		1.1	TB	
LE000108.E10	RE000108.E10	16	162		0.8	TB	
LE000109.E10	RE000109.E10	27	165		0.9	TB	
LE000110.E10	RE000110.E10	71	122		0.5	TB	
LE000111.E10	RE000111.E10	75	216		0.6	TB	
LE000112.E10	RE000112.E10	188	89		0.4	TB	
LE000113.E10	RE000113.E10	209	151		0.4	TB	
LE000114.E10	RE000114.E10	189	229		0.5	TB	*5*
LE000115.E10	RE000115.E10	235	96		0.7	TB	
LE000116.E10	RE000116.E10	239	69		0.5	TB	
LE000117.E10	RE000117.E10	279	193		0.4	TB	
LE000118.E10	RE000118.E10	390	46		0.5	TB	
LE000119.E10	RE000119.E10	421	75		0.4	TB	*9*
LE000120.E10	RE000120.E10	419	111		0.5	TB	
LE000121.E10	RE000121.E10	485	208		0.4	TB	
LE000122.E10	RE000122.E10	465	161		0.4	TB	
LE000123.E10	RE000123.E10	492	116		0.5	TB	
LE000124.E10	RE000124.E10	614	73		0.5	TB	
LE000125.E10	RE000125.E10	671	50		0.4	TB	
LE000126.E10	RE000126.E10	653	113		0.5 x 0.8	TB	
LE000127.E10	RE000127.E10	829	109		0.3	TB	
LE000128.E10	RE000128.E10	859	99		0.4	TB	
LE000129.E10	RE000129.E10	929	176		0.5	TB	
LE000130.E10	RE000130.E10	928	122		0.4	TB	
LE000131.E10	RE000131.E10	958	153		0.5	TB	
LE000132.E10	RE000132.E10	1015	16		0.9	TB	*9*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000133.E10	RE000133.E10	1032	73		0.9	TB	
LE000134.E10	RE000134.E10	1042	137		0.5	TB	
LE000135.E10	RE000135.E10	1149	177		0.4	TB	
LE000136.E10	RE000136.E10	1220	39		0.4	TB	*14*
LE000137.E10	RE000137.E10	1194	174		0.5	TB	
LE000138.E10	RE000138.E10	1200	85		0.5	TB	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

TB - Thermal Blanket (Teflon, silver-inconel, binder, and paint).

1 - Lighting in image is from the right gooseneck light only.
2 - Impact crater is located in the experiment-tray serial number.
3 - Wrong coordinates (X = 530, Y = 816) input into image file.
4 - Wrong coordinates (X = 563, Y = 807) input into image file.
5 - Impact feature has no rings or halo.
6 - Wrong coordinates (X = 747, Y = 799) input into image file.
7 - Wrong coordinates (X = 735, Y = 813) input into image file.
8 - Image taken at 60° below normal of crater.
9 - Impact into velcro attachment for thermal blanket.
10 - Higher magnification view of same feature.
11 - Wrong magnification (6x) input into image file.
12 - Penetration into velcro with definite crater visible; diameters listed are penetration, crater.
13 - Lower magnification view of same feature.
14 - Lighting in image is from the left gooseneck light only.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-372/11
On-Orbit - S32-78-065
Pre-Deintegration - KSC-390C-1028.12, KSC-390C-1029.02, KSC-390C-1029.06
Post Deintegration
M&D SIG Photos - S90-43547 and S90-43548 - Left 1/3 of thermal blanket, straight-on front and backlit back views.
S90-43549 and S90-43550 - Center 1/3 of thermal blanket, straight-on front and backlit back views.
S90-43551 and S90-43552 - Right 1/3 of thermal blanket, straight-on front and backlit back views.

ARCHIVED MATERIALS:

Clamps - E10C01, E10C05, E10C07, and E10C08
Clamp Bolts - E10S05C
Thermal Blanket - (E10E00A) - The U.S. third (minus the specimen removed for the Materials SIG) resides at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds are being archived at ESTEC in the Netherlands. Each blanket third was marked with two small crosses (see Fiducial Mark table above) for indexing and reconstruction purposes.
Other - E10E01 - Aluminum grounding strap connector

LDEF LOCATION: E11
EXPERIMENT IDENTIFICATION: S0001
EXPERIMENT TITLE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES

493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay E11 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays which were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the proposed leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 335 features on the E11 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of these, 270 features from all surfaces were found which were smaller in diameter than the 0.5 mm photodocumentation threshold; 28 of these were located on the experiment-tray clamps, 41 were located on the experiment-tray flanges, and the other 201 were located on the aluminum tray surface. Of the remaining 65 features, 51 were photodocumented from the aluminum collector surfaces, 45 of which were between 0.5 mm and 1.0 mm in diameter, five were between 1.0 mm and 1.5 mm in diameter, and one was between 2.0 mm and 2.5 mm in diameter. Twelve features were found on the tray flanges; ten of these measured between 0.5 mm and 1.0 mm in diameter, and two measured between 1.0 mm and 1.5 mm in diameter. Only two features were photodocumented on the various clamping hardware associated with this tray. Both were between 0.5 mm and 1.0 mm in diameter and one each resided on clamps C02 and C05. All features exhibited characteristics typical of craters formed in aluminum during laboratory hypervelocity impact experiments.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	28	41	201	270
>0.5 mm	2	12	51	65
TOTALS	30	53	252	335

The largest impact feature found on this tray measured ~2.4 mm in diameter, which included a reddish ejecta plume, and was present on one of the aluminum collection plates at the base of the tray.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection (February 21, 1990) was conducted while the experiment tray was mounted on the spacecraft and identified five features which might be damaged by the attachment of the experiment-tray cover and two additional features which could be damaged or destroyed by the placing of the experiment tray within the experiment-tray rotator stand. These latter were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the more interesting features within

the experiment-tray cover area, the cover gasket was cut in four locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There was one spallation feature located on the front of the 0.0625" (1.6 mm) thick experiment-tray flange, but this feature was not damaged during the tray deintegration process.

DOCUMENTATION:

Examination and photodocumentation of tray E11, associated clamps, and bolts were accomplished on March 21 & 22, 1990 in the horizontal position utilizing M&D SIG System #3. The clamps and bolts associated with this tray were scanned with M&D SIG System #3 on March 21, 1990. The coordinates for all features were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC020001.E11	RC020001.E11	95	44		0.5	Al	
LC050001.E11	RC050001.E11	51	14		0.9	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.E11	RE000001.E11	708	-17		0.5	Al	
LE000002.E11	RE000002.E11	934	-3		0.5	Al	
LE000054.E11	RE000054.E11	865	972		1.1	Al	
LE000055.E11	RE000055.E11	612	965		ND	Al	
LE000056.E11	RE000056.E11	80	958		0.5	Al	
LE000057.E11	RE000057.E11	1265	813		0.6	Al	*3*
LE000058.E11	RE000058.E11	1300	722		0.7	Al	
LE000059.E11	RE000059.E11	1285	100		0.6	Al	
AE000059.E11	BE000059.E11	1285	100		0.6	Al	
LE000060.E11	RE000060.E11	940	955	55	0.5	Al	*4,d,f*
LE000061.E11	RE000061.E11	0	577	13	0.5	Al	*4,f*
LE000062.E11	RE000062.E11	1130	0	25	1.4	Al	*4,f*
LE000063.E11	RE000063.E11	1040	0	52	0.6	Al	*4,f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000003.E11	RE000003.E11	110	65		0.7 x 0.8	Al	
LE000004.E11	RE000004.E11	435	50		1.0	Al	
LE000005.E11	RE000005.E11	580	60		0.5	Al	
LE000006.E11	RE000006.E11	605	30		0.8	Al	
LE000007.E11	RE000007.E11	360	90		0.7	Al	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000008.E11	RE000008.E11	370	105		0.6	Al	
LE000009.E11	RE000009.E11	435	107		0.6	Al	
LE000010.E11	RE000010.E11	525	105		0.7	Al	
LE000011.E11	RE000011.E11	42	210		0.7	Al	
LE000012.E11	RE000012.E11	145	235		0.5	Al	*k*
LE000013.E11	RE000013.E11	270	345		0.6	Al	
LE000014.E11	RE000014.E11	340	245		0.6	Al	
LE000015.E11	RE000015.E11	495	235		0.6	Al	
LE000016.E11	RE000016.E11	594	345		0.7	Al	
LE000017.E11	RE000017.E11	252	395		2.4	Al	*1*
LE000018.E11	RE000018.E11	70	385		0.7	Al	
LE000019.E11	RE000019.E11	103	440		1.1	Al	
LE000020.E11	RE000020.E11	1017	75		0.9	Al	
LE000021.E11	RE000021.E11	1135	92		0.7	Al	*2*
LE000022.E11	RE000022.E11	1120	115		0.7	Al	
LE000023.E11	RE000023.E11	1140	133		0.5	Al	*w*
LE000024.E11	RE000024.E11	1090	235		0.8	Al	
LE000025.E11	RE000025.E11	955	265		0.6	Al	
LE000026.E11	RE000026.E11	990	282		0.8	Al	
LE000027.E11	RE000027.E11	750	330		0.5	Al	
LE000028.E11	RE000028.E11	750	455		0.8	Al	
LE000029.E11	RE000029.E11	1092	373		1.5	Al	
LE000030.E11	RE000030.E11	1200	383		1.1	Al	
LE000031.E11	RE000031.E11	450	880		0.5	Al	
LE000032.E11	RE000032.E11	85	847		1.2	Al	
LE000033.E11	RE000033.E11	48	828		0.7	Al	
LE000034.E11	RE000034.E11	293	793		0.7	Al	
LE000035.E11	RE000035.E11	265	682		0.7	Al	
LE000036.E11	RE000036.E11	377	735		0.7	Al	
LE000037.E11	RE000037.E11	347	612		0.5	Al	
LE000038.E11	RE000038.E11	1190	775		0.8	Al	
LE000039.E11	RE000039.E11	1232	755		0.7	Al	
LE000040.E11	RE000040.E11	1227	720		0.8	Al	
LE000041.E11	RE000041.E11	1105	660		0.6	Al	
LE000042.E11	RE000042.E11	1025	640		0.6	Al	
LE000043.E11	RE000043.E11	675	660		0.8	Al	
LE000044.E11	RE000044.E11	66	693		0.5	Al	
LE000045.E11	RE000045.E11	695	710		0.8	Al	
LE000046.E11	RE000046.E11	893	765		0.8	Al	
LE000047.E11	RE000047.E11	785	495		0.6	Al	
LE000048.E11	RE000048.E11	865	585		0.8	Al	
LE000049.E11	RE000049.E11	888	550		0.6	Al	
LE000050.E11	RE000050.E11	960	505		0.8	Al	
LE000051.E11	RE000051.E11	1195	475		0.5	Al	
LE000052.E11	RE000052.E11	1175	27		0.7	Al	
LE000053.E11	RE000053.E11	467	933		0.7	Al	*x*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Reddish ejecta material is present.
2 - Wrong coordinates (X = 1175, Y = 27) input into image file.
3 - Incorrectly input into image file as located on upper tray flange; actually located on right tray flange.
4 - Image taken at 45° from normal to crater.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-78-53
Pre-Deintegration - KSC-390C-1028.09, KSC-390C-1028.11, KSC-390C-1028.04
Post Deintegration - KSC-390C-2162.04
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - E11C01, E11C02, E11C05, and E11C08
Clamp Bolt - E11S02C

ACCOMPANYING FIGURES:

See Figure A05-1

LDEF LOCATION: E12
EXPERIMENT IDENTIFICATION: A0038
EXPERIMENT TITLE: INTERSTELLAR-GAS EXPERIMENT
PRINCIPAL INVESTIGATOR: D.L. LIND
UTAH STATE UNIVERSITY
LOGAN, UTAH 84335-4415

SUMMARY OF OBSERVATIONS

The A0038 experimental package consisted of four 12"-deep (30.5 cm), active experiment trays (two peripheral [E12 and F06] and two space-end [H06 and H09]) designed to collect interstellar-gas atoms within metal foils at various times and locations around the Earth. In addition to particle collection, the experiment called for the isotopic analyses on recovered particles in the hopes of revealing the composition of the interstellar wind. The experiment exposed 15 μm thick, high-purity Cu-Be collecting foils (five per detector) which were housed within aluminum detector boxes; underlying each foil was an aluminum plate which was in contact with the foil in most cases. Each box possessed a viewing angle between 35° and 41° and was capped by electron and high-voltage ion suppression grids. In general, there were two such units per A0038 experiment tray; Bay F06 housed only one such detector. Unfortunately, the sequencing of the foils did not function properly for what is believed to have been grounding problems.

The Cu-Be detection foils were removed from the aluminum housings and examined in detail by the M&D SIG A-Team for penetrations and craters. Most of the foil penetrations and resulting craters in the underlying aluminum substrate exhibited a rather interesting morphologic relationship. The underlying craters were commonly offset from the penetration hole suggesting the projectile path to be at some angle to the normal of the foil's surface. The foils themselves were generally raised off of the aluminum substrate as the result of the penetration/crater-forming event. Morphologically, these features resemble small volcanic cone structures. Features examined which were located in the various pieces of aluminum hardware associated with the experiment tray and experimental hardware were typical of features produced in aluminum targets utilizing controlled laboratory conditions. Painted aluminum surfaces commonly exhibited paint spall zones in association with the crater. One feature (LE000004.E12) located on the bottom of tray E12 apparently resulted from the impact of a fluffy-type (*i.e.*, loosely aggregated materials) projectile. This feature was acquired by the M&D SIG, as were several others from the A0038 experimental trays (see Archived Materials list, below).

The M&D SIG survey identified a total of 206 features on the various components of tray E12 including the assorted experimental surfaces, as well as the experiment-tray bolts, clamps, shims, and flanges associated with the tray. One hundred twenty five of these features were <0.5 mm in diameter and located on the experiment-tray flanges and 12"-deep (30.5 cm), inner-tray walls. Seven other features on these surfaces were between 0.5 and 1.0 mm in diameter and were photodocumented. Fifty <0.5 mm diameter features were counted on the various surfaces of the detector housings and the painted aluminum bottom surface of the tray. Only seven features were above the 0.5 mm photodocumented threshold, one of which was located in the head of a screw. Nine features were identified from the clamps (C01-C08), six of which were <0.5 mm in diameter, and three of which were between 0.5 and 1.0 mm in diameter.

The Cu-Be foil canisters were removed from the experiment tray by the Principal Investigator and the M&D SIG was allowed to survey and image the foils. When imaged, the cassette 08 foils were assigned the component identification of "E08". Six of the eleven features found during the detailed examination of the Cu-Be foils were photodocumented, only two of which were between 0.3 and 1.0 mm in diameter; all of the remaining features on these surfaces were <0.3 mm in diameter, including two on the aluminum support frames for the foils.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			7	7
>0.3 mm			2	2
<0.5 mm	6	125	50	181
>0.5 mm	3	7	6	16
TOTALS	9	132	65	206

The largest impact features identified were (1) an ~0.8 mm diameter impact located on the inner-tray wall, (2) an ~1.4 mm feature on one of the detector housings, (3) an ~0.4 mm diameter penetration through one of the Cu-Be foils, and (4) an ~1.1 mm crater in clamp C01.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection (February 21, 1990) was conducted while the experiment tray was mounted on the spacecraft and identified only two features which might be damaged by the emplacement of the experiment-tray cover. In an effort to protect the most interesting feature within the experiment-tray cover area, the cover gasket was cut in one location to prevent it from coming into contact with this feature and to provide a stand-off for the experiment-tray cover and the tray flanges. No features were identified within the experiment-tray rotator stand clamping area of the experiment-tray flanges. One feature each was identified on clamps C01, C02, and C07, while two features each were found on clamps C03, C04, and C08.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of tray E12 was conducted on March 6 and 7, 1990 in the vertical position utilizing M&D SIG Systems #2 and #3. System #2 was utilized during the initial tray documentation, while System #3 was the one used for documentation of features within the various Cu-Be foils. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3. Coordinates for all features on all surfaces associated with tray E12 were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC010001.E12	RC010001.E12	800	330		1.1	Al	
LC040001.E12	RC040001.E12	24	40		0.7	Al	
LC080001.E12	RC080001.E12	21	31		0.6	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.E12	RE000001.E12	264	962		ND	Al	
LE000002.E12	RE000002.E12	-25	648		ND	Al	
LE000003.E12	RE000003.E12	1246	750		ND	Al	
LE000009.E12	RE000009.E12	401	-48		0.7	Al	
LE000010.E12	RE000010.E12	233	-28		0.5	Al	
LE000011.E12	RE000011.E12	535	15	75	0.8	Al	*f*
LE000012.E12	RE000012.E12	0	132	158	0.8	Al	*f*
LE000013.E12	RE000013.E12	0	300	120	0.8	Al	*f*
LE000014.E12	RE000014.E12	1080	420	200	1.4	Al	*f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000004.E12	RE000004.E12	610	500	300	0.7	Al	*3,b,g*
LE000005.E12	RE000005.E12	530	325	300	0.5 x 0.8	Al	*3,b,g*
LE000006.E12	RE000006.E12	540	315	300	0.5	Al	*3,b,g*
LE000007.E12	RE000007.E12	104	180	300	0.8	Al	*1,g*
AE000007.E12	BE000007.E12	104	180	300	0.8	Al	*1,g*
LE000008.E12	RE000008.E12	198	445	297	0.8	Al	*2,d*
AE000008.E12	BE000008.E12	198	445	297	0.8	Al	*2,d*
LE000015.E12	RE000015.E12	1090	420	40	0.8	Al	
LE080001.E12	RE080001.E12	80	54		0.4	Cu-Be, Al	
LE080002.E12	RE080002.E12	100	121		0.2	Cu-Be, Al	
LE080003.E12	RE080003.E12	145	82		0.1	Cu-Be, Al	
LE080004.E12	RE080004.E12	220	79		0.2	Cu-Be, Al	
LE080005.E12	RE080005.E12	223	100		0.3	Cu-Be, Al	
LE080006.E12	RE080006.E12	145	82		0.2	Cu-Be, Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Impact into electronics access cover plate.
2 - Impact into screw.
3 - Painted aluminum surface.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-538/12
On-Orbit - S32-78-31
Pre-Deintegration - KSC-390C-1069.04, KSC-390C-1069.06, KSC-390C-1069.09
Post Deintegration - KSC-390C-1600.02, KSC-390C-1601.10, KSC-390C-1602.06
M&D SIG Photos - None

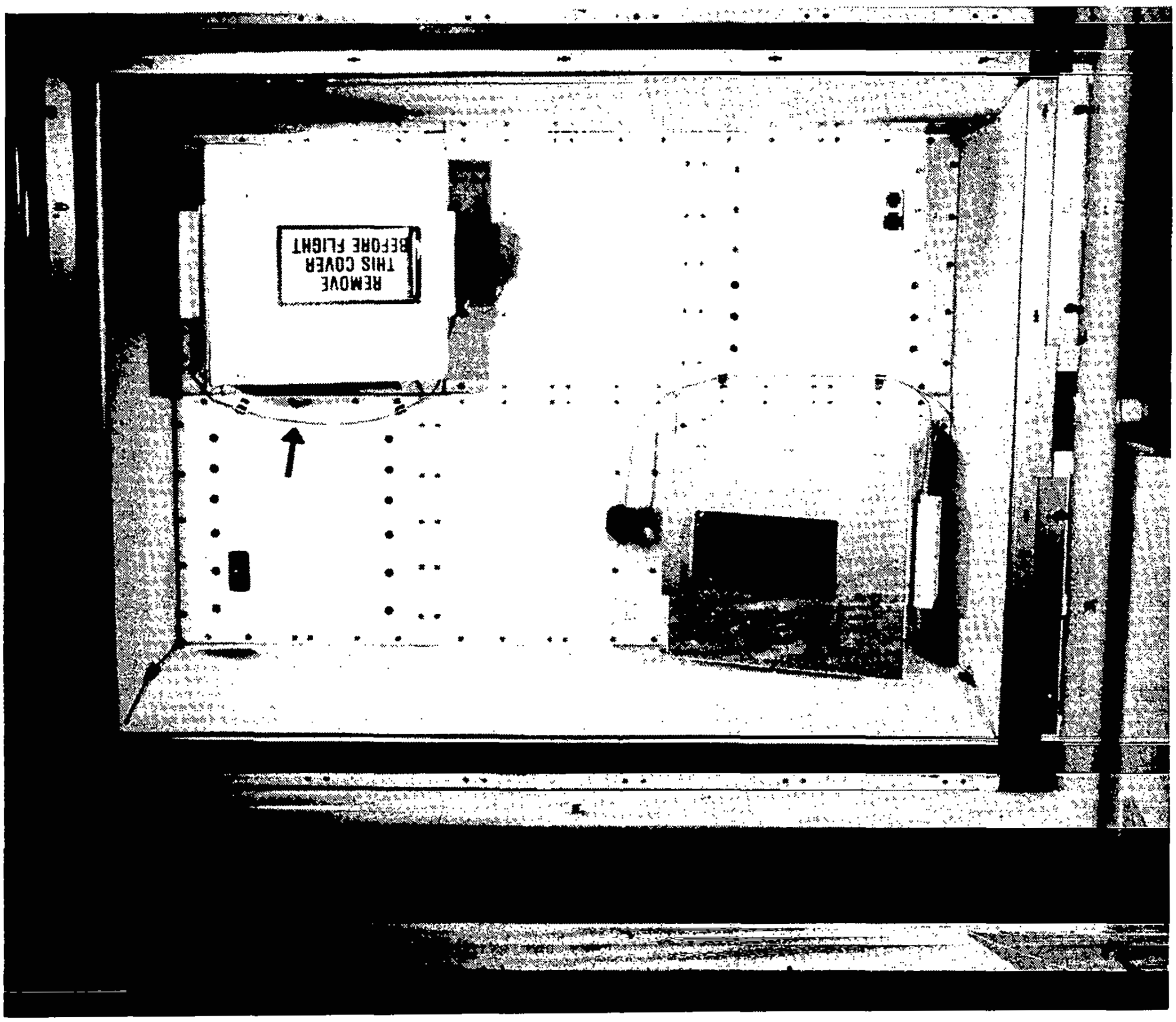
ARCHIVED MATERIALS:

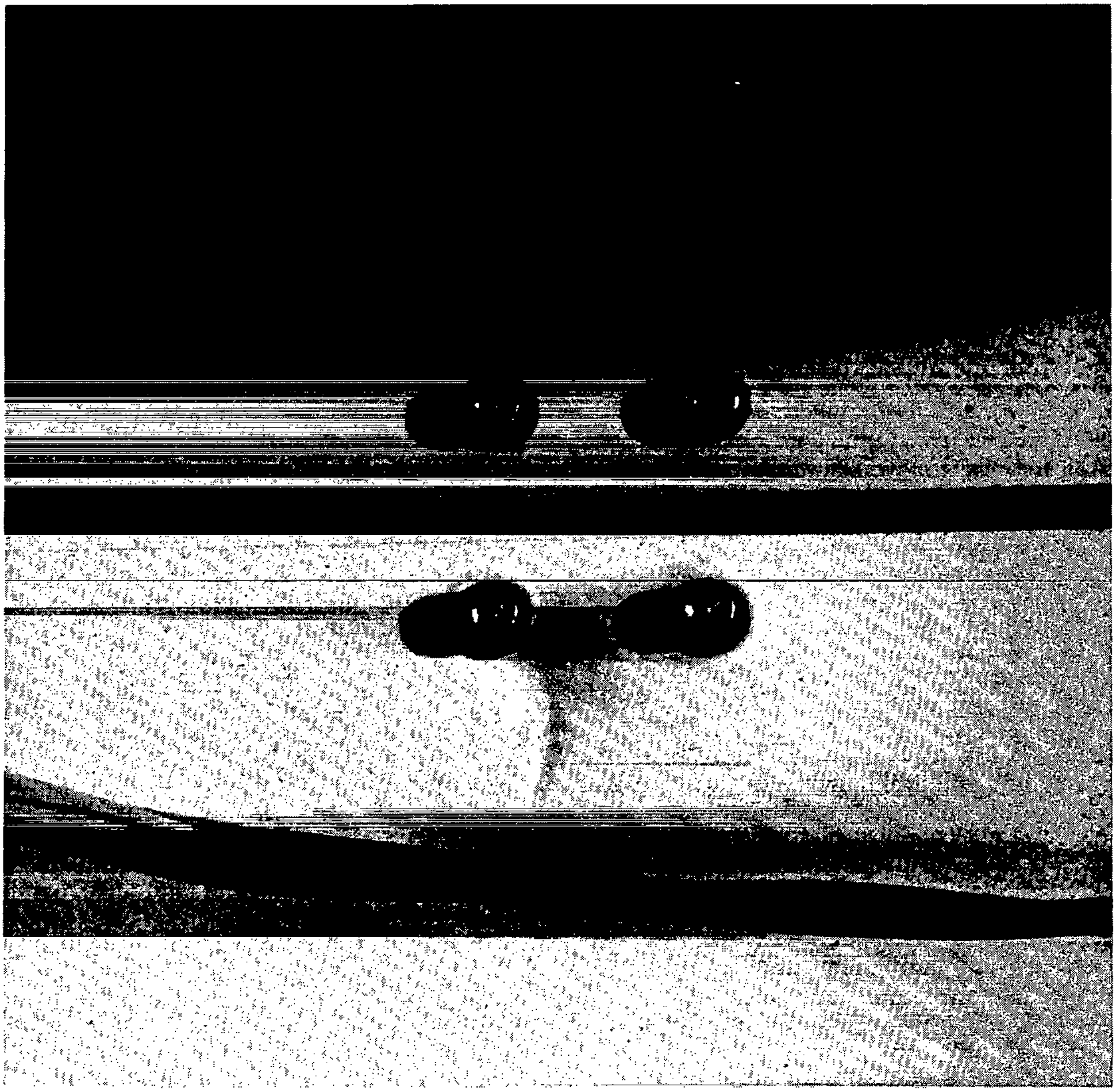
Clamps - E12C01, E12C03, E12C04, and E12C08
Cores - E12E00,4 (LD-5) Feature LE000004.E12
E12E00,5 (LD-6) Feature LE000005.E12
E12E00,6 (LD-7) Feature LE000006.E12
E12E00,7 (LD-8) Feature LE000007.E12
E12E00,8 (LD-4) Feature LE000008.E12
E12E00,16 (LD-3) Feature LE0000016.E12
E12S01,8 (LD-2) Feature LE000008.E12

ACCOMPANYING FIGURES:

Figure E12-1. This post-deintegration view shows the front of the entire E12 experiment tray. The space-exposed interstellar gas collector foils have been covered in this view. An arrow points to the impact feature (#8) shown in Figure E12-2.

Figure E12-2. This view shows an ejecta spall pattern resulting from an impact (#8) into the lower left bolt head. View measures approximately 11 cm across.





LDEF LOCATION: F01
EXPERIMENT IDENTIFICATION: S0001
EXPERIMENT TITLE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES

493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay F01 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays which were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

There were a total of 91 features visually identified on all F01 surfaces, three of which were on the 0.19" (4.8 mm) thick, 6061-T6 chromic anodized aluminum tray clamps. Of the remaining 88 features, 71 were <0.5 mm in diameter and were not imaged. No information on the general locations (*i.e.*, experiment-tray flanges, walls or, experimental surfaces) of these small features was recorded. One of the remaining 17 features was ~0.6 mm in diameter, but was located in a corner and could not be imaged properly. Of the 16 imaged features, two were on the experiment-tray flange, four were on the inner-tray walls, and ten were on the experimental aluminum surfaces.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	2			73*
>0.5 mm	1	7	10	18
TOTALS	3			91*

* The location of the "Too Smalls" was not documented.

The largest feature identified on tray F01 was an oblique, multi-cratering event (LE000011.F01) which measured ~0.5 x 1.3 mm located on the experiment-tray flange. Dozens of small craters were observed within the main large crater. A second multi-crater feature (LE000006.F01) similar in morphology, but more symmetrical in overall structure, was found in the experimental aluminum surface and measured ~0.7 mm in diameter; this feature had a reddish-colored debris associated with it. Two other features with associated reddish-colored debris deposits were found on the experimental surfaces, an oblique feature (LE000005.F01) which measured ~0.5 x 1.0 mm and had a one-sided debris deposition, and an ~0.8 mm diameter feature (LE000006.F01) with a symmetrical deposition of debris surrounding it.

The two multi-cratering events described above represent very rare events on LDEF. Only about a dozen such features, in the visually detectable size range (>0.1 mm), were found on the entire spacecraft by the M&D SIG during their detailed surveys of the spacecraft.

M&D SIG INSPECTIONS

PRE-DEINTEGRATION:

Three features >0.5 mm in diameter were identified on the experiment-tray flanges during the initial inspection of tray F01 on February 21, 1990 when the tray was still mounted to LDEF. One of these features resided in the area which would be contacted by the experiment-tray cover gasket, and a slice of the gasket was removed to avoid possible damage to the feature. One feature <0.5 mm in diameter was identified on each of two clamps, C03 and C05.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.2 mm) thick, chromic-anodized, 6061-T6 experiment-tray flanges.

DOCUMENTATION:

Tray F01, as well as all experiment-tray clamps, bolts, and shims, was inspected in the horizontal position on the M&D SIG work bench (Position 5) with M&D SIG System #3 on March 19, 1990. Feature coordinates were determined using a metric tape measure.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC050001.F01	RC050001.F01	20	30		0.6	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000011.F01	RE000011.F01	1100	972		0.4 x 1.3	Al	*j,x*
LE000012.F01	RE000012.F01	425	973		0.5	Al	
LE000013.F01	RE000013.F01	1019	0	60	0.6	Al	*f*
LE000014.F01	RE000014.F01	834	0	40	0.8	Al	*f*
LE000015.F01	RE000015.F01	742	0	18	0.8	Al	*f*
LE000016.F01	RE000016.F01	590	0	35	0.3 x 0.6	Al	*f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.F06	RE000001.F01	167	310		0.5	Al	
LE000002.F01	RE000002.F01	410	625		0.4 x 0.6	Al	
LE000003.F01	RE000003.F01	430	882		0.6	Al	
LE000004.F01	RE000004.F01	681	85		0.7	Al	
LE000005.F01	RE000005.F01	695	148		0.5 x 1.0	Al	*d*
AE000005.F01	BE000005.F01	695	148		0.5 x 1.0	Al	d
LE000006.F01	RE000006.F01	025	45		0.7	Al	*1,d,j*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000007.F01	RE000007.F01	987	468		0.8	Al	
LE000008.F01	RE000008.F01	904	717		0.7	Al	
LE000009.F01	RE000009.F01	829	513		0.6	Al	
LE000010.F01	RE000010.F01	764	815		0.6	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Higher magnification view.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-78-36
Pre-Deintegration - KSC-390C-1069.01, KSC-390C-1069.03, KSC-390C-1066.07
Post Deintegration - KSC-390C-2158.05
M&D SIG Photos: - None

ARCHIVED MATERIALS:

Clamps - F01C01, F01C02, F01C04, and F01C05

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION:	**F02**
EXPERIMENT IDENTIFICATION:	**P0004-1**
EXPERIMENT TITLE:	**SEEDS IN SPACE EXPERIMENT**
PRINCIPAL INVESTIGATOR:	**J.A. ALSTON** **GEORGE W. PARK SEED CO., INC.** **GREENWOOD, SOUTH CAROLINA**
	P0004-2 **SPACE-EXPOSED EXPERIMENT DEVELOPED FOR STUDENTS (SEEDS)** **NASA HEADQUARTERS** **WASHINGTON, D.C.**
	P0006 **LINEAR ENERGY TRANSFER SPECTRUM MEASUREMENT EXPERIMENT** **E.V. BENTON** **UNIVERSITY OF SAN FRANCISCO** **SAN FRANCISCO, CALIFORNIA**

SUMMARY OF OBSERVATIONS

Bay F02 housed an integrated, 6"-deep (15.2 cm) passive experiment tray containing the SEEDS Experiments (P0004-1 and P0004-2) and the Linear Energy Transfer Spectrum Measurements Experiment (P0006). The experiment tray was covered by an ~200 μm thick Scheldahl G411500 thermal blanket, identical to those covering the sixteen A0178 experiments, which was mounted flush with the experiment-tray flanges. The thermal blanket consisted of an outer layer (facing space) of FEP Teflon (~120 μm thick) backed with a thin layer of silver-inconel (~200 to 300 Å thick), which in turn was backed by Chemglaze Z306 black conductive paint and binding medium (~80 to 100 μm thick). The structure and attachments for the experiment tray consisted of the tray flanges and walls (0.125" [3.2 mm] thick chromic anodized 6061-T6 aluminum), the experiment-tray clamps (0.19" [4.8 mm] thick chromic anodized 6061-T6 aluminum), and the experiment-tray clamp bolts (303 stainless steel). The backs of the tray was also covered with a reflective thermal blanket.

Because penetration mechanics differ from true cratering mechanics in the size of resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for the blanket surface were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The scientific objective of the Seeds in Space Experiment (P0004-1) was to expose approximately two million seeds of many varieties to the near-Earth space environment. Upon their return to Earth the seeds would be germinated along with a similar batch of "control seeds" to study the effects of the space exposure on the germination rates and the overall plant development (*e.g.*, whether or not more mutations occur). The seeds were packaged within Dacron bags and placed within a sealed 12" (30.5 cm) diameter, white painted aluminum structure which was capped with a 0.05" (1.3 mm) thick aluminum dome, and a vented ~5" (~12.7 cm) diameter container. Within these structures the seeds were stacked or layered to investigate the effects of increased shielding on the seeds; monitoring equipment within the containers included dosimeters between

each layer of seeds and passive, maximum-temperature indicators. An additional black painted container was attached to the bottom of the experiment tray.

Experiment P0004-2 was similar to experiment P0004-1 in that it housed approximately 11 to 12 million tomato seeds within five identical 12" (30.5 cm) domed containers. Upon their return to Earth, returned tomato seeds were germinated at the Park Seed Co., found to be viable, and offered for distribution to students. The seeds were offered to students along with a pack of "control seeds" to permit the students to carry out classroom experiments to gather information and evaluate the effects of space exposure on the tomato seeds.

Scientifically, P0006 was to measure the Linear Energy Transfer (LET) spectrum behind various shielding configurations. The degree of aluminum shielding increased by 1 g/cm^2 up to a maximum of 16 g/cm^2. The experiment was housed within an ~5" (~12.7 cm) diameter, 3" (7.6 cm) high cylindrical, aluminum canister (identical in size to the vented P0004-1 canister). Inside this canister was a combination of thermal luminescence and track-type detectors.

Penetrations through the F02 thermal blanket typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted Teflon material. Commonly, the Teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. When impacts occurred into the velcro which supported the thermal blanket materials, large delamination areas were very common around the penetration. Many penetrations possessed several sharp, distinct, colored rings, while others exhibited a more continuous halo phenomenon where the change from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impacts into aluminum.

During the detailed inspection of the thermal blanket covering the F02 tray, the M&D SIG identified 27 features between 0.3 mm and 1.0 mm in diameter for detailed microscopic inspection and potential photodocumentation. Of these, only two features ~0.3 mm were photodocumented due to time constraints. However, unlike the A0178 thermal blankets where the M&D SIG acquired the left one-third only, the entire F02 thermal blanket was taken to the Johnson Space Center for detailed examination and curation. Three features (one each) were photodocumented from clamps C02, C03, and C06, all of which were <0.5 mm in diameter; the feature on clamp C02 was located on the edge of the clamp. The survey for "Too Small" features was not performed for this experiment tray.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm				27*@
>0.3 mm				
<0.5 mm	3			*@
>0.5 mm				
TOTALS	3			30*@

* The location and sizes of features were not documented.

@ The survey for the "Too Smalls" was incomplete.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection (February 20, 1990) was conducted while the experiment tray was mounted on the spacecraft and identified no features in either the experiment-tray cover or experiment-tray rotator stand areas. One feature each was identified on clamps C02, C03, and C06.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick experiment-tray flanges. Inspection of the back side of tray F02 revealed the presence of a rainbow-type discoloration pattern which apparently resulted from an outgassing source in the direction of Row 1. In addition, the thermal blanket possessed a tire-track type pattern running vertically along the right edge of the blanket (see NASA photo KSC-390C-2336.12). This pattern was apparently the result of "bubble-wrap" coming into contact with this material at some time in it's history.

DOCUMENTATION:

Examination and photodocumentation of tray F02 was conducted on February 26, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #1. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Fiducial Mark Locations - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC020001.F02	RC020001.F02	47	2		0.4	Al	
LC030001.F02	RC030001.F02	112	46		0.5	Al	
LC060001.F02	RC060001.F02	38	1		0.3	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.F02	RE000001.F02	212	806		0.3	TB	
LE000002.F02	RE000002.F02	307	453		0.1 x 0.3	TB	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

TB - Thermal Blanket (Teflon, silver-inconel, binder, and paint)

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-299/5
On-Orbit - S32-89-023
Pre-Deintegration - KSC-390C-1065.07, KSC-390C-1065.09, KSC-390C-1065.10
Post Deintegration - KSC-390C-1465.01, KSC-390C-1465.02, KSC-390C-1465.03, KSC-390C-2336.12, KSC-90PC-330, KSC-90PC-331, KSC-90PC-332, KSC-90PC-334, KSC-90PC-335, KSC-390C-1464.01 through KSC-390C-1464.12, KSC-390C-1466.01 through KSC-390C-1466.12, KSC-390C-1457.01 through KSC-390C-1457.12, KSC-390C-1459.01 through KSC-390C-1459.12
M&D SIG Photos - S90-43445 through S90-43456 - Tray F02 tray removal operations.
S90-43457, S90-43458 - Left 1/3 of Thermal Blanket; front and back views.
S90-43460, S90-43461 - Center 1/3 of Thermal Blanket; front and back views.
S90-43462, S90-43463 - Right 1/3 of Thermal Blanket; front and back views.
S90-43464 - Tray F02 following removal of the thermal blanket.

ARCHIVED MATERIALS:

Clamps - F02C02, F02C03, F02C04, and F02C07
Thermal Blanket - (F02E00A, F02E00B, and F02E00C) - The U.S. acquired the entire blanket, sectioned it into thirds, and shipped it (minus the Materials SIG specimen) to the Johnson Space Center, Houston, Texas.

LDEF LOCATION: F03
EXPERIMENT IDENTIFICATION: S0001
EXPERIMENT TITLE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES
493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay F03 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays which were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 61 features on the F03 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of these, 51 features from all surfaces were found to be smaller in diameter than the 0.5 mm photodocumentation threshold. Of these 51 features, four were located on the experiment-tray clamps, 19 were located on the experiment-tray flanges, and 28 were located on the aluminum experimental surfaces. Nine features were photodocumented from the aluminum collector surfaces, of which six were between 0.5 mm and 1.0 mm in diameter and three were between 1.0 mm and 1.5 mm in diameter. No features were found on the experiment-tray flanges which were large enough to photodocument. Only one feature was identified on the various clamping hardware associated with this tray, and it was located on clamp C05 and measured ~0.5 mm in diameter. All features exhibited characteristics typical of craters formed in aluminum during laboratory hypervelocity impact experiments.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	4	19	28	51
>0.5 mm	1		9	10
TOTALS	5	19	37	61

The two largest impact features found on this tray measured ~1.5 mm in diameter and were both located on the aluminum experimental tray surfaces.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

An initial inspection of this tray was performed on February 20, 1990 while the experiment tray was mounted on the spacecraft in order to document features which might be altered during tray deintegration. No such features were located, although one feature was found on clamp C05.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges or spallation features on the 0.0625" (1.6 mm) thick experiment-tray flanges or backside.

DOCUMENTATION:

Examination and photodocumentation of tray F03 was conducted on March 26, 1990 in the horizontal position utilizing M&D SIG System #3. The bolts, clamps, and shims associated with this tray were also scanned and imaged with M&D SIG System #3. The coordinates for all features associated with this tray were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC050001.F03	RC050001.F03	1	5		0.5	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.F03	RE000001.F03	534	191		0.8	Al	
LE000002.F03	RE000002.F03	600	385		1.5	Al	
LE000003.F03	RE000003.F03	130	720		0.8	Al	*x*
LE000004.F03	RE000004.F03	281	750		0.6	Al	*x*
LE000005.F03	RE000005.F03	1155	313		0.5	Al	*x*
LE000006.F03	RE000006.F03	746	495		0.8	Al	*x*
LE000007.F03	RE000007.F03	834	482		1.3	Al	*x*
LE000008.F03	RE000008.F03	403	594		0.7	Al	*x*
LE000009.F03	RE000009.F03	629	472		1.5	Al	*1,d,e,x*
AE000009.F03	BE000009.F03	629	472		1.5	Al	*1,2,d,e,w*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Ejecta material drapes over the interface between the two aluminum experiment plates.
2 - Image taken at 45° from normal to crater.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-85-17
Pre-Deintegration - KSC-390C-1065.01, KSC-390C-1065.03, KSC-390C-833.07, KSC-390C-833.08
Post Deintegration - KSC-390C-2288.10
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - F03C01, F03C04, F03C05, and F03C08

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION:	**F04**
EXPERIMENT IDENTIFICATION:	**A0178**
EXPERIMENT TITLE:	**A HIGH-RESOLUTION STUDY OF ULTRA-HEAVY COSMIC-RAY NUCLEI**
PRINCIPAL INVESTIGATOR:	**D. O'SULLIVAN DUBLIN INSTITUTE FOR ADVANCED STUDIES DUBLIN, IRELAND**

SUMMARY OF OBSERVATIONS

Bay F04 held one of sixteen 12"-deep (30.5 cm), passive experiment trays composing the A0178 experiment. Each tray contained three ~46"-long (116.8 cm), 10" (25.4 cm) diameter aluminum cylinders which enclosed the polymer-sheet track detectors surrounded by Eccofoam. The tray was thermally decoupled from the LDEF spacecraft and insulated with a ~200 μm thick Scheldahl G411500 thermal blanket which was mounted flush with the experiment-tray flanges. Each thermal blanket consisted of an outer layer (facing space) of FEP Teflon (~120 μm thick) backed with a thin layer of silver-inconel (~200 to 300 Å thick), which in turn is backed by Chemglaze Z306 black conductive paint and binding medium (~80 to 100 μm thick). The structure and attachments for the experiment tray consisted of the tray flanges and walls (0.125" [3.2 mm] thick chromic anodized 6061-T6 aluminum), the experiment-tray clamps (0.19" [4.8 mm] thick chromic anodized 6061-T6 aluminum), and the experiment-tray clamp bolts (303 stainless steel). The backs of the trays were also covered with a reflective thermal blanket.

From the M&D SIG point of view, the A0178 thermal blankets provided a large, uniform meteoroid detection surface randomly spaced around the spacecraft; only Rows 3, 9, and 12 did not house an A0178 experiment tray. Furthermore, because penetration mechanics differ from true cratering mechanics in the size of resulting features produced *via* impact, the M&D SIG A-Team lowered its threshold feature diameter from 0.5 mm to 0.3 mm for the purposes of photodocumentation. Therefore, features classified as "Too Small" for these surfaces were <0.3 mm in diameter; the threshold value of 0.5 mm in diameter was still used for features located on the aluminum experiment-tray flanges.

The penetrations through the thermal blankets typically possessed a central circular- to elliptical-shaped hole surrounded by a raised lip of melted Teflon material. Commonly, the Teflon layer would be separated or delaminated from the underlying layers of the blanket for up to 10 or more penetration-hole diameters around the penetration hole. When impacts occurred into the velcro which supported the thermal blanket materials, large delamination areas were very common around the penetration. Many penetrations possessed several sharp, distinct, colored rings, while others exhibited a more continuous halo phenomenon where the change from one color or ring to another was more diffuse or gradational. However, all rings/halos were not circular in appearance. The morphology of the features located on the experiment-tray flanges were all typical of hypervelocity impacts into aluminum.

The M&D SIG survey identified a total of 52 features on the F04 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the thermal insulation blanket. Of these, 36 were found on the thermal blanket, all but a few representing penetrations through the blanket. Twenty eight features on the blanket were below the 0.3 mm diameter photodocumentation threshold and eight features were between 0.3 mm and 1.0 mm in diameter. Nine features were found on the tray flanges, none of which were documented as they were all <0.5 mm in diameter. One of these features was disfigured/destroyed by clamping the tray into the tray rotator stand. The remaining seven features were located while scanning the associated bolts, clamps, and shims for tray F04, all of which were <0.5 mm in diameter and not photodocumented.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			28	28
>0.3 mm			8	8
<0.5 mm	7	9		16
>0.5 mm				
TOTALS	7	9	36	52

The largest impact feature identified was an ~1.0 mm diameter penetration hole through the thermal blanket.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection (February 22, 1990) was conducted while the experiment tray was mounted on the spacecraft and identified only one feature which could be damaged or destroyed by the placing of the experiment tray within the experiment-tray rotator stand.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of tray F04 was conducted on March 22, 1990 in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #3. The bolts, clamps, and shims associated with this tray were scanned with M&D SIG System #3.

Bolt-Hole Registration - Not Determined

Fiducial Mark Locations - Not Determined

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.F04	RE000001.F04	355	790		0.4 x 0.6	TB	
LE000002.F04	RE000002.F04	475	820		0.5	TB	
LE000003.F04	RE000003.F04	565	745		0.3	TB	
LE000004.F04	RE000004.F04	1195	745		0.3	TB	
LE000005.F04	RE000005.F04	575	425		1.0	TB	
LE000006.F04	RE000006.F04	775	425		0.7	TB	
LE000007.F04	RE000007.F04	915	540		0.6	TB	
LE000008.F04	RE000008.F04	670	240		0.4	TB	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

TB - Thermal Blanket (Teflon, silver-inconel, binder, and paint).

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-371/1
On-Orbit - S32-77-036
Pre-Deintegration - KSC-390C-1065.06, KSC-390C-1065.05, KSC-390C-832.02, KSC-390C-832.01
Post Deintegration - KSC-390C-2212.04
M&D SIG Photos - S90-43538, S90-43539, S90-43540 - Left 1/3 of Thermal Blanket; 2 front- and 1 back views.
S90-43536, S90-43537 - Center 1/3 of Thermal Blanket; front and back views.
S90-43534, S90-43535 - Right 1/3 of Thermal Blanket; front and back views.

ARCHIVED MATERIALS:

Clamps - F04C01, F04C04, F04C05, and F04C08
Clamp Bolts - F04S04B
Clamp Shims - F04H04, F04H06
Thermal Blanket - (F04E00A) - The U.S. third (minus the Materials SIG specimen) reside at the Johnson Space Center, Houston, Texas, while the remaining European two-thirds (minus the Materials SIG grounding-strap specimen) is being archived at ESTEC in The Netherlands. This Thermal Blanket was processed by the M&D SIG A-Team before the decision was made to place such marks on the thermal-blanket surface.

LDEF LOCATION: F05
TRAY IDENTIFICATION: S0001
EXPERIMENT PURPOSE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES
493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay F05 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays which were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 112 features on the F05 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of the 112 impacts found, 102 were < 0.5 mm and were not imaged. Of the remaining 10 which were imaged, nine ranged in diameter from 0.6 mm to 1.0 mm and one was ~1.7 mm in diameter. Of the 10 imaged impacts, two were located on the tray flanges, one was located on tray-clamp C05, and the remaining seven impacts were located on the Al tray surface. All features were typical of craters produced in aluminum during laboratory hypervelocity impact tests.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	4			102*
>0.5 mm	1	2	7	10
TOTALS	5	2	7	112

* The location of the "Too Smalls" was not documented.

The largest impact feature identified on tray F05 was a circular impact ~1.7 mm in diameter located on the experimental tray surface.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 22, 1990 while the experiment tray was mounted on the spacecraft. The M&D SIG identified two features which might be damaged by the attachment of the experiment-tray cover and four additional features which could be damaged or destroyed by placing the experiment tray within the experiment-tray rotator stand. Although two features were identified which might be damaged by the attachment of the experiment-tray cover, no gaskets were cut to prevent this damage.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations of the 0.0625" (1.6 mm) thick experiment-tray flanges and no bulges or spalls on the back of the tray flanges.

DOCUMENTATION:

On March 6, 1990, the S0001 tray, along with its bolts and clamps, was inspected in the horizontal position. Both inspections utilized M&D SIG System #3 and the impact coordinates for all features were determined using a metric tape measure.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC050001.F05	RC050001.F05	91	10		0.6	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000008.F05	RE000008.F05	517	950	59	0.6	Al	*f,1*
LE000009.F05	RE000009.F05	0	835	65	0.6	Al	*f,1*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.F05	RE000001.F05	61	17		0.8	Al	
LE000002.F05	RE000002.F05	770	21		0.6	Al	
LE000003.F05	RE000003.F05	351	210		0.6	Al	
LE000004.F05	RE000004.F05	471	397		0.8	Al	*2*
LE000005.F05	RE000005.F05	733	292		1.7	Al	*3*
LE000006.F05	RE000006.F05	215	554		0.9	Al	
LE000007.F05	RE000007.F05	187	565		0.9	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Image taken at 30° from normal.
2 - Angle of microscope was 30° when image was taken.
3 - Angle of microscope was 5° when image was taken.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-77-045
Pre-deintegration - KSC-390C-1035.04, KSC-390C-1035.10, KSC-390C-1035.12
Post Deintegration - KSC-390C-1658.09
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - F05C01, F05C05, F05C06, and F05C07
Clamp Bolts - F05S01B, F05S01C, F05S03A, F05S05A, and F05S07B
Clamp Shims - F05H07

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION: F06
EXPERIMENT IDENTIFICATION: A0038
EXPERIMENT TITLE: INTERSTELLAR-GAS EXPERIMENT
PRINCIPAL INVESTIGATOR: D.L. LIND
UTAH STATE UNIVERSITY
LOGAN, UTAH 84335-4415

SUMMARY OF OBSERVATIONS

The A0038 experimental package consisted of four 12"-deep (30.5 cm), active experiment trays (two peripheral [E12 and F06] and two space-end [H06 and H09]) designed to collect interstellar-gas atoms within metal foils at various times and locations around the Earth. In addition to particle collection, the experiment called for isotopic analyses on recovered particles in the hopes of revealing the composition of the interstellar wind. The experiment exposed 15 μm thick, high-purity Cu-Be collecting foils (five per detector) which were housed within aluminum detector boxes; underlying each foil was an aluminum plate which was in contact with the foil in most cases. Each box possessed a viewing angle between 35° and 41° and was capped by electron and high-voltage ion suppression grids. In general, there were two such units per A0038 experiment tray; Bay F06 housed only one such detector. Unfortunately, the sequencing of the foils did not function properly for what is believed to have been grounding problems.

After the detailed inspection of the integrated experiment tray by the M&D SIG, the Cu-Be detection foils were removed from their aluminum housing by the Principal Investigator and examined in detail by the M&D SIG A-Team for penetrations and craters. Most of the foil penetrations and resulting craters in the underlying aluminum substrate exhibited a rather interesting morphologic relationship. The underlying craters were commonly offset from the penetration holes suggesting the projectile path to be at some angle to the normal of the foil's surface. The foils themselves were generally raised off of the aluminum substrate as the result of the penetration/crater-forming event. Morphologically, these features resemble small volcanic cone structures. Features examined which were located in the various pieces of aluminum hardware associated with the experiment tray and experimental hardware were typical of feature produced in aluminum targets utilizing controlled laboratory conditions. Painted aluminum surfaces commonly exhibited paint spall zones in association with the craters.

The M&D SIG survey identified a total of 123 features on the F06 experiment-tray hardware including the experiment-tray bolts, clamps, shims, and flanges, as well as the units housing the Cu-Be collector foils. No features were noted on the Cu-Be foils from this tray. One hundred six of the identified features were <0.5 mm in diameter on all tray hardware. Nine features which were between 0.5 and 1.0 mm in diameter were photodocumented on the experiment-tray flanges and inner-tray walls. Two additional features of undetermined size were located under the experiment-tray clamping mechanism and could not be examined or measured; these features are included in the <0.5 mm column in the Feature Summary table below. Only two features were photodocumented from the painted aluminum, bottom surface of the experimental tray. One of these was ~0.7 mm in diameter and the other was ~1.6 mm in diameter. An additional five features between 0.5 and 1.0 mm in diameter were photodocumented from clamps C02 (1), C05 (2), C06 (1), and C08 (1).

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	4			108*
>0.5 mm	5	9	2	16
TOTALS	9			124*

* The location of the "Too Smalls" was not documented.

The largest impact features identified were (1) an ~1.6 mm feature on the painted aluminum base plate, (2) an ~0.9 mm feature on the left experiment-tray flange, and (3) three ~0.6 mm features on clamps C02, C06, and C08.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection (February 22, 1990) was conducted while the experiment tray was mounted on the spacecraft and identified three features which might be damaged by the emplacement of the experiment-tray cover and two additional features which could be damaged or destroyed by placing the experiment tray within the experiment-tray rotator stand. In an effort to protect the most interesting of the features within the experiment-tray cover area, the cover gasket was cut in one location to prevent it from coming into contact with this feature and to provide a stand-off for the experiment-tray cover and the tray flanges. One feature each was identified on clamps C02, C06, C07, and C08, while four features were identified on clamp C05.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of tray F06 was conducted on March 6, 1990 in the vertical position utilizing M&D SIG System #2, while the bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3. The coordinates for all photodocumented features associated with tray F06 were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC020001.F06	RC020001.F06	480	470		0.6	Al	
LC050001.F06	RC050001.F06	31	28		0.5	Al	
LC050002.F06	RC050002.F06	68	32		0.5	Al	
LC060001.F06	RC060001.F06	97	42		0.6	Al	
LC080001.F06	RC080001.F06	29	4		0.6	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.F06	RE000001.F06	-30	842		0.9	Al	
LE000002.F06	RE000002.F06	355	930		0.8	Al	1
LE000003.F06	RE000003.F06	786	925	20	0.8	Al	1,f
LE000004.F06	RE000004.F06	1245	412		0.5	Al	
LE000005.F06	RE000005.F06	727	-40		0.5	Al	k
LE000006.F06	RE000006.F06	24	0	15	0.6	Al	2,f

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000009.F06	RE000009.F06	445	814	165	0.7	Al	*f*
LE000010.F06	RE000010.F06	1139	915	80	0.5	Al	*f*
LE000011.F06	RE000011.F06	139	905	120	0.8	Al	*6,f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000007.F06	RE000007.F06	810	82	300	1.6	Al	*3,4,7,b*
LE000008.F06	RE000008.F06	588	595	300	0.7	Al	*3,5,b*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Image taken at 45° from normal of crater.
2 - Image taken at 40° from normal of crater.
3 - White painted aluminum.
4 - Spall zone ~3.6 mm in diameter.
5 - Spall zone ~1.3 mm in diameter.
6 - Image taken at 15° from normal of crater.
7 - Image taken using 0.4 mm lower objective.

OTHER PHOTODOCUMENTATION:

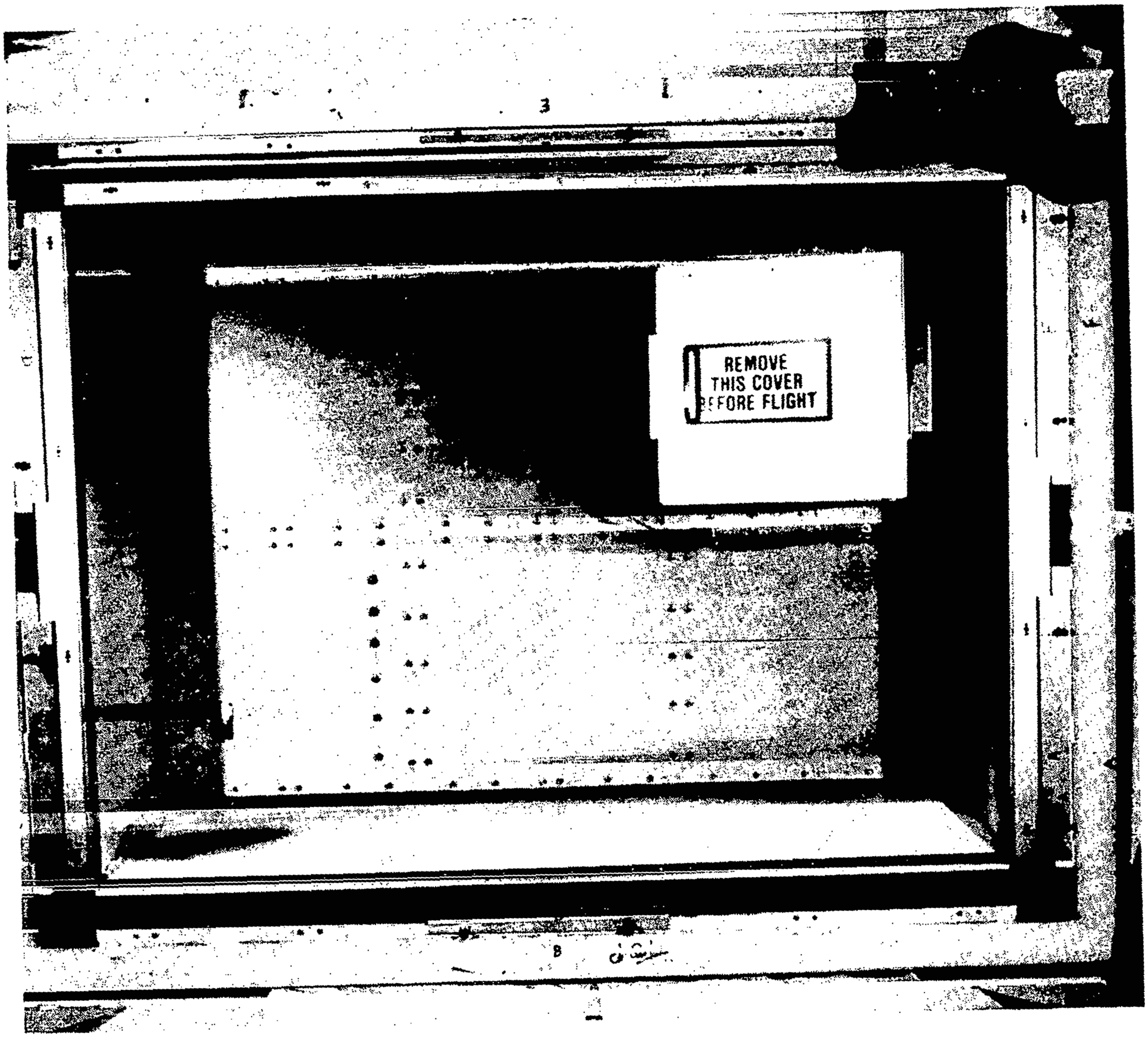
Pre-Flight - 108-KSC-384C-538/4
On-Orbit - S32-82-2
Pre-Deintegration - KSC-390C-1033.01, KSC-390C-1033.03, KSC-390C-1033.04, KSC-390C-1033.07, KSC-390C-1033.08
Post Deintegration - KSC-390C-1563.03, KSC-390C-1563.04, KSC-390C-1563.05, KSC-390C-1563.06
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - F06C02, F06C05, F06C07, and F06C08

ACCOMPANYING FIGURES:

Figure F06-1. This post-deintegration view shows the front of the entire F06 experiment tray. The space-exposed interstellar gas collector foils have been covered in this view.


REMOVE
THIS COVER
BEFORE FLIGHT

LDEF LOCATION: F07
EXPERIMENT IDENTIFICATION: S0001
EXPERIMENT TITLE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES

493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay F07 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays which were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 320 features on the F07 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the aluminum detector surface of the S0001 experiment. The distribution between the experimental surfaces and the experiment-tray flanges for the <0.5 mm diameter features was not recorded for this tray; two hundred fifty five features fall into this category. An additional 26 features <0.5 mm in diameter were identified, 21 of which were on the various clamps associated with the F07 tray; four others were found during the detailed inspection of the aluminum detector surfaces and one additional feature in this size range was found on the experiment-tray flanges. The remaining 39 features were photodocumented. These consisted of six between 0.5 and 1.0 mm and one between 1.0 and 1.5 mm in diameter on the experiment-tray flanges, one feature between 0.5 and 1.0 mm in diameter on clamp C01, and 28 features between 0.5 and 1.0 mm, two features between 1.0 and 1.5 mm, and one feature between 1.5 and 2.0 mm in diameter on the aluminum detector surfaces of the S0001 experiment. All features examined were typical of craters formed in aluminum under hypervelocity laboratory conditions.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	21			281*
>0.5 mm	1	7	31	39
TOTALS	22			320*

* The location of the "Too Smalls" was not documented.

The largest impact features identified were (1) an ~1.1 mm diameter feature on the top, inner-tray wall, (2) an ~1.7 mm feature with debris spray on the upper-left quadrant of the S0001 experimental aluminum surface, and (3) an ~0.6 mm diameter feature on clamp C01.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection (February 22, 1990) was conducted while the experiment tray was mounted on the spacecraft and identified three features which might be damaged by the emplacement of the experiment-tray cover and two additional features which could be damaged or destroyed by placing the experiment tray within

the experiment-tray rotator stand. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges. One feature with associated debris was identified on clamp C04 during this survey.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of tray F07 was conducted on March 8, 1990 in the horizontal position utilizing M&D SIG System #3. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #2. Coordinates for all features associated with the F07 tray were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC010001.F07	RC010001.F07	93	29			Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.F07	RE000001.F07	551	-15		0.5	Al	
LE000002.F07	RE000002.F07	130	-42		0.5	Al	
LE000003.F07	RE000003.F07	-4	74		0.7	Al	
LE000004.F07	RE000004.F07	-17	575		0.9	Al	*k,w*
LE000019.F07	RE000019.F07	262	954		0.7	Al	*x*
LE000031.F07	RE000031.F07	414	952	17	1.1	Al	*1,f*
LE000032.F07	RE000032.F07	1277	359		0.8	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000005.F07	RE000005.F07	425	460		0.8	Al	*d,y*
LE000006.F07	RE000006.F07	114	394		1.0	Al	*y*
LE000007.F07	RE000007.F07	214	122		0.8	Al	
LE000008.F07	RE000008.F07	543	149		0.6	Al	
LE000009.F07	RE000009.F07	229	43		0.8	Al	*2,d*
LE000010.F07	RE000010.F07	1150	464		0.6	Al	
LE000011.F07	RE000011.F07	1184	393		1.0	Al	
LE000012.F07	RE000012.F07	1013	355		0.5	Al	*2*
LE000013.F07	RE000013.F07	1025	352		1.4	Al	*2*
LE000014.F07	RE000014.F07	896	267		0.6	Al	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000015.F07	RE000015.F07	1239	280		0.6	Al	*3*
LE000016.F07	RE000016.F07	1048	223		0.7	Al	
LE000017.F07	RE000017.F07	957	112		0.7	Al	
LE000018.F07	RE000018.F07	966	37		0.7	Al	
LE000020.F07	RE000020.F07	530	922		0.5	Al	*x*
LE000021.F07	RE000021.F07	389	887		0.6	Al	*k,x*
LE000022.F07	RE000022.F07	400	862		0.8	Al	*x*
LE000023.F07	RE000023.F07	605	855		1.7	Al	*d,x*
LE000024.F07	RE000024.F07	208	880		0.5	Al	*x*
LE000025.F07	RE000025.F07	370	728		0.6	Al	*x*
LE000026.F07	RE000026.F07	365	706		0.6	Al	*x*
LE000027.F07	RE000027.F07	394	691		0.8	Al	*x*
LE000028.F07	RE000028.F07	65	614		0.6	Al	*x*
LE000029.F07	RE000029.F07	25	576		0.5	Al	*x*
LE000030.F07	RE000030.F07	156	539		0.6	Al	*x*
LE000033.F07	RE000033.F07	812	885		0.7	Al	*x*
LE000034.F07	RE000034.F07	1210	825		0.7	Al	*x*
LE000035.F07	RE000035.F07	775	641		0.7	Al	*d,x*
LE000036.F07	RE000036.F07	935	616		0.8	Al	*x*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Image taken at 30° from normal of crater.
2 - Image rotated 10° counter-clockwise.
3 - Image rotated 60° clockwise.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-82-26
Pre-Deintegration - KSC-390C-1032.01, KSC-390C-1032.02, KSC-390C-1032.08, KSC-390C-1032.10
Post Deintegration - KSC-390C-2160.09
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - F07C01, F07C04, F07C06, and F07C08
Clamp Shims - F07H01

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION: F08
EXPERIMENT IDENTIFICATION: M0004
EXPERIMENT TITLE: SPACE ENVIRONMENT EFFECTS ON FIBER OPTICS SYSTEMS
PRINCIPAL INVESTIGATOR: E.W. TAYLOR
AIR FORCE WEAPONS LABORATORY
KIRTLAND AIR FORCE BASE
ALBUQUERQUE, NEW MEXICO

SUMMARY OF OBSERVATIONS

Bay F08 contained a 6"-deep (15.2 cm), partially active experiment tray which housed the M0004 Fiber Optics Experiment. The goal of the M0004 experiment was to evaluate the effects of the near-Earth space environment on hardened fiber-optics data link bundles. Degradation of the transmissivity of these fiber optics will be determined by comparing post-flight data with data obtained prior to the flight of the LDEF spacecraft. The total M0004 package consisted of nine distinct experiments, both active and passive. Of the four active experiments, one consisted of a 45 m cabled glass fiber, while the other active fibers consisted of plastic-coated silica (two of which were 20 m long and one which measured 48 m in length). Three 10 m pre-irradiated data links were included within the F08 tray volume to investigate the effects of increased radiation damage on such materials; various pre-irradiated LED's and photodiodes were incorporated within the tray volume as well. All of the associated electronics (*e.g.*, emitters, detectors, connectors, couplers) were shielded.

Impacts located in the various fiber-optics bundles differed in morphology as a function of the size of the projectile. Smaller and/or lower-velocity projectiles which did not penetrate the plastic coating of the fiber-optics cables resembled craters produced in polymers under laboratory hypervelocity conditions. Such craters commonly possess a raised rim of melted plastic and a pit or crater exhibiting a smooth, melted morphology. Projectiles of sufficient mass and/or velocity which penetrated the fiber-optics coating generally produced a penetration-hole type morphology in the fiber-optics coating material. The optical fibers varied in their degree of damage from simple breakage and splintering, to various degrees of melting; such features generally exhibited a relatively rough or irregular crater shape. Several features were examined which represented complete penetrations through the edge of a fiber-optics bundle. Such features commonly possessed a roughly circular or hemispherical outline, while the polymer coatings and optical fibers exhibited morphologies similar to those previously described.

All aluminum surfaces on the M0004 experiment were painted. Features examined in these surfaces displayed interesting morphological characteristics, commonly exhibiting a ringed appearance (see NASA photographs KSC-390C-1937.04 and KSC-390C-1937.06). Virtually all features >0.2 mm in diameter possessed a spall zone in which all of the paint was removed from the aluminum surface. Such spall zones varied in size from approximately two to five crater diameters (similar responses of painted aluminum surfaces were documented on the four LDEF scuff plates). The actual craters in the aluminum substrate varied from central pits without raised rims, to morphologies more typical of craters formed in aluminum under hypervelocity, laboratory condition for the larger features. Most of the features possessed what were termed as "shock zones" by the M&D SIG A-Team. These zones varied in size from approximately one to as much as 30 crater diameters. In most cases, only the outer-most layer of the paint was effected by this impact related phenomenon. Several impacts possessed ridge-like structures ringing the area in which this outer-most paint layer was removed. In many ways, such features resembled basin-sized lunar craters, but on an extremely reduced scale. Lastly, several features were noted in the painted aluminum surfaces immediately around the fiber-optics bundles which were nearly identical in appearance to the penetration features on the various A0178 thermal blankets (*i.e.*, multiple-ringed features). This multiple-ringed morphology for craters was found only on a few of the surfaces flown on the LDEF spacecraft (*e.g.*, the abutment plate of the C10 active grapple fixture). As with the other painted aluminum surface previously described, a paint spall zone was commonly found in association

with the central pit or crater (see NASA photographs KSC-390C-1937.02, KSC-390C-1938.01, and KSC-390C-1938.02). Around this spall zone was an area of discoloration varying in size from five to ten spall-zone diameters. At least one of these areas appeared as though the outer-most layer of the paint had been removed. The remaining rings (2 to ~10) appeared as little more than discolorations in the paint.

The M&D SIG survey identified a total of 593 features on all surfaces of the F08 experiment tray. Of the 562 features identified as being <0.5 mm in diameter, 45 resided on the experiment-tray flanges, 46 were on the various clamps associated with the F08 tray, and 471 were counted from the painted aluminum surfaces and fiber-optics bundles (457 and 14, respectively). Thirty one features were photodocumented, of which one was on a fiber-optics bundle, 17 resided on the painted aluminum surfaces, six were found on the experiment-tray flanges, and one feature was located on clamp C08; all 25 of these features were between 0.5 and 1.0 mm in diameter. Of the remaining six features, all but one (between 1.5 and 2.0 mm in diameter on the painted aluminum surfaces) were between 1.0 and 1.5 mm in diameter (one on the experiment-tray flange and four on the painted aluminum surface). Several other features were noted on the various fiber-optics bundles, but were not examined or photodocumented at the request of the PI. M&D SIG A-Team personnel examining this tray noted the presence of numerous ~10 μm diameter features in the painted aluminum surfaces, but did not count the entire surface for features in this size range. In an ~4" x 4" area which was counted, 50 such features were noted.

The painted aluminum shield for the electronics on this tray was deintegrated by the Principal Investigator and provided to the M&D SIG for additional inspection. This was assigned the component designation "E01" and two images were taken of back-surface paint spall zones caused by front surface impacts.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	46	45	471	562
>0.5 mm	1	7	23	31
TOTALS	47	52	494	593

The largest impact features identified were (1) an ~1.4 mm diameter feature on the experiment-tray flange and (2) an ~1.3 mm feature located on one of the painted aluminum surfaces.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection (February 22, 1990) was conducted while the experiment tray was mounted on the spacecraft and identified seven features which might be damaged by the emplacement of the experiment-tray cover and two features which could be damaged or destroyed by clamping the experiment tray within the experiment-tray rotator stand. These latter features were not examined or documented, nor were they included in the numerical summary given above. At the request of the PI, the experiment-tray cover gasket was not cut to protect any of these features. No features residing on the various 6061-T6 chromic anodized, aluminum tray clamps were identified during the initial survey.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick, 6061-T6 chromic anodized experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of tray F08 was conducted on March 14, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #2. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	66	959	59	-17
Center	625	959	617	-15
Far Right	1184	960	1176	-15

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC080001.F08	RC080001.F08	8	78			Al	*25*

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000012.F08	RE000012.F08	1250	378		1.4	Al	*27*
LE000015.F08	RE000015.F08	6	417		0.7	Al	
LE000016.F08	RE000016.F08	795	975		0.8	Al	
LE000017.F08	RE000017.F08	976	972		0.6	Al	
LE000018.F08	RE000018.F08	1258	854		0.8	Al	*27*
LE000025.F08	RE000025.F08	838	-34		0.8	Al	*1*
LE000030.F08	RE000030.F08	1091	-4		0.8	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.F08	RE000001.F08	221	394		0.8	FO	
AE000001.F08	BE000001.F08	221	394		0.8	FO	*26*
LE000002.F08	RE000002.F08	1043	659		1.0	Al (painted)	*2,b*
LE000003.F08	RE000003.F08	843	717		1.1	Al (painted)	*3,b*
LE000004.F08	RE000004.F08	847	663		0.6	Al (painted)	*4,b*
LE000005.F08	RE000005.F08	1133	582		1.0	Al (painted)	*5,b*
LE000006.F08	RE000006.F08	960	393		0.7	Al (painted)	*6,b*
LE000007.F08	RE000007.F08	1134	419		0.7	Al (painted)	*7,b*
LE000008.F08	RE000008.F08	1133	322		0.7	Al (painted)	*8,b*
LE000009.F08	RE000009.F08	1132	281		0.7	Al (painted)	*9,b*
LE000010.F08	RE000010.F08	1047	283		1.3	Al (painted)	*10,b,i*
LE000011.F08	RE000011.F08	1007	336		0.5	Al (painted)	*11,b*
LE000013.F08	RE000013.F08	468	474		0.8	Al (painted)	
LE000014.F08	RE000014.F08	479	743		1.0	Al (painted)	*12,b*
LE000019.F08	RE000019.F08	809	872		0.7	Al (painted)	*13,b*
LE000020.F08	RE000020.F08	503	806		0.5	Al (painted)	*14,b*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000021.F08	RE000021.F08	875	938		0.8	Al (painted)	*15,b*
LE000022.F08	RE000022.F08	1065	914		1.0	Al (painted)	*16,b*
LE000023.F08	RE000023.F08	1212	885		0.7	Al (painted)	*17,b*
LE000024.F08	RE000024.F08	1156	730		0.7	Al (painted)	*18,b*
LE000026.F08	RE000026.F08	1072	195		0.8	Al (painted)	*19,b*
LE000027.F08	RE000027.F08	980	108		0.5	Al (painted)	*20,b,i*
LE000028.F08	RE000028.F08	907	110		0.7	Al (painted)	*21,b*
LE000029.F08	RE000029.F08	910	76		0.7	Al (painted)	*22,b*
LE010010.F08	RE010010.F08	1055	275		ND	Al	*23,b,i*
LE010027.F08	RE010027.F08	995	102		ND	Al	*24,b,i*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined
FO - Fiber-Optics Bundle

1 - Image taken 30° from normal of crater.
2 - Spall-zone D_2 = 1.7 mm, Shock-zone D_3 = 30.0 mm; apparent paint flake in bottom of crater.
3 - Spall-zone D_2 = 2.2 mm, Shock-zone D_3 = 30.0 mm.
4 - Spall-zone D_2 = 2.2 mm, Shock-zone D_3 = 18.0 mm.
5 - Spall-zone D_2 = 2.0 mm, Shock-zone D_3 = 18.0 mm.
6 - Spall-zone D_2 = 1.8 mm, Shock-zone D_3 = 17.0 mm.
7 - Spall-zone D_2 = 1.8 mm, Shock-zone D_3 = 18.5 mm.
8 - Spall-zone D_2 = 1.0 mm, Shock-zone D_3 = 11.0 mm, D_4 = 15.0 mm, D_5 = 21.0 mm.
9 - Spall-zone D_2 = 1.5 mm, Shock-zone D_3 = 7.5 mm.
10 - Spall-zone D_2 = 2.2 mm, Shock-zone D_3 = 44.0 mm.
11 - Spall-zone D_2 = 2.1 mm, Shock-zone D_3 = 7.5 mm.
12 - Spall-zone D_2 = 2.2 mm, Shock-zone D_3 = 28.0 mm, D_4 = 30.0 mm, D_5 = 32.0 mm.
13 - Spall-zone D_2 = 2.3 mm.
14 - Spall-zone D_2 = 1.7 mm.
15 - Spall-zone D_2 = 2.2 mm, Shock-zone D_3 = 20.0 mm.
16 - Spall-zone D_2 = 2.0 mm, Shock-zone D_3 = 30.0 mm.
17 - Spall-zone D_2 = 1.5 mm, Shock-zone D_3 = 15.0 mm.
18 - Spall-zone D_2 = 1.8 mm, Shock-zone D_3 = 20.0 mm.
19 - Spall-zone D_2 = 1.8 mm, Shock-zone D_3 = 17.0 mm.
20 - Spall-zone D_2 = 1.0 mm.
21 - Spall-zone D_2 = 1.8 mm, Shock-zone D_3 = 20.0 mm.
22 - Spall-zone D_2 = 2.1 mm, Shock-zone D_3 = 19.0 mm.
23 - Image of rear-surface spall zone D_{spall} = 1.4 mm; believed to be associated with front-side Feature #10 (LE000010.F08) although coordinates are different.
24 - Image of rear-surface spall zone D_{spall} = 1.3 mm; associated with front-side Feature #27 (LE000027.F08).
25 - Impact into paint specimen.
26 - Higher magnification view of LE000001.F08; microscope light source on low.
27 - Image illuminated with left microscope light-pipe only.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-293/7
On-Orbit - S32-76-20
Pre-Deintegration - KSC-390C-1031.03, KSC-390C-1031.05, KSC-390C-1031.06, KSC-390C-1031.07
Post Deintegration - KSC-390C-1934.05, KSC-390C-1934.06, KSC-390C-1935.07 through KSC-390C-1935.11, KSC-390C-1936.08, KSC-390C-1937.02 through KSC-390C-1937.07, KSC-390C-1938.01, KSC-390C-1938.02, KSC-390C-1168.10
M&D SIG Photos - S90-43421

ARCHIVED MATERIALS:

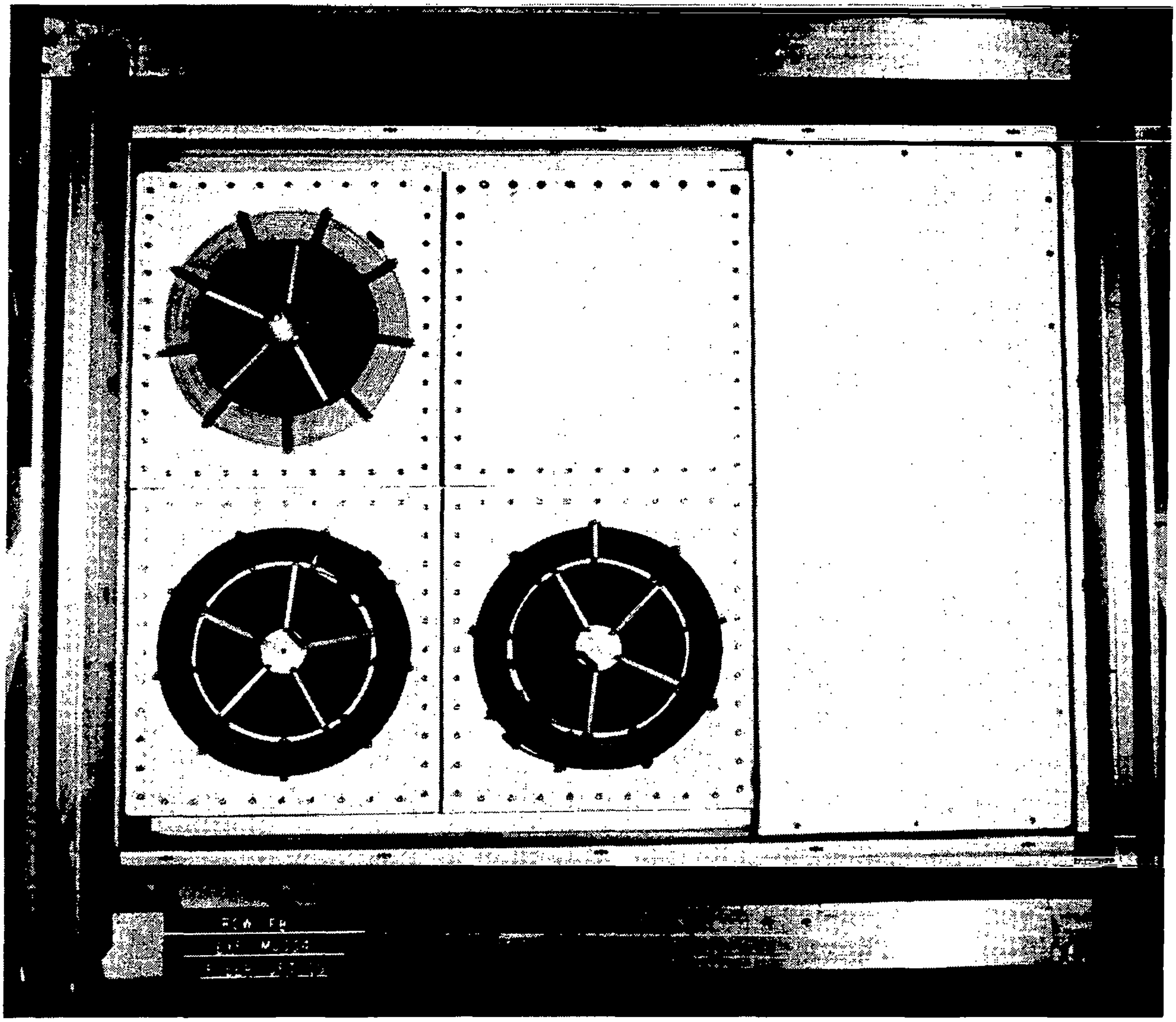
Clamps - F08C01, F08C05, F08C07, and F08C08
Clamp Bolts - F08S04B

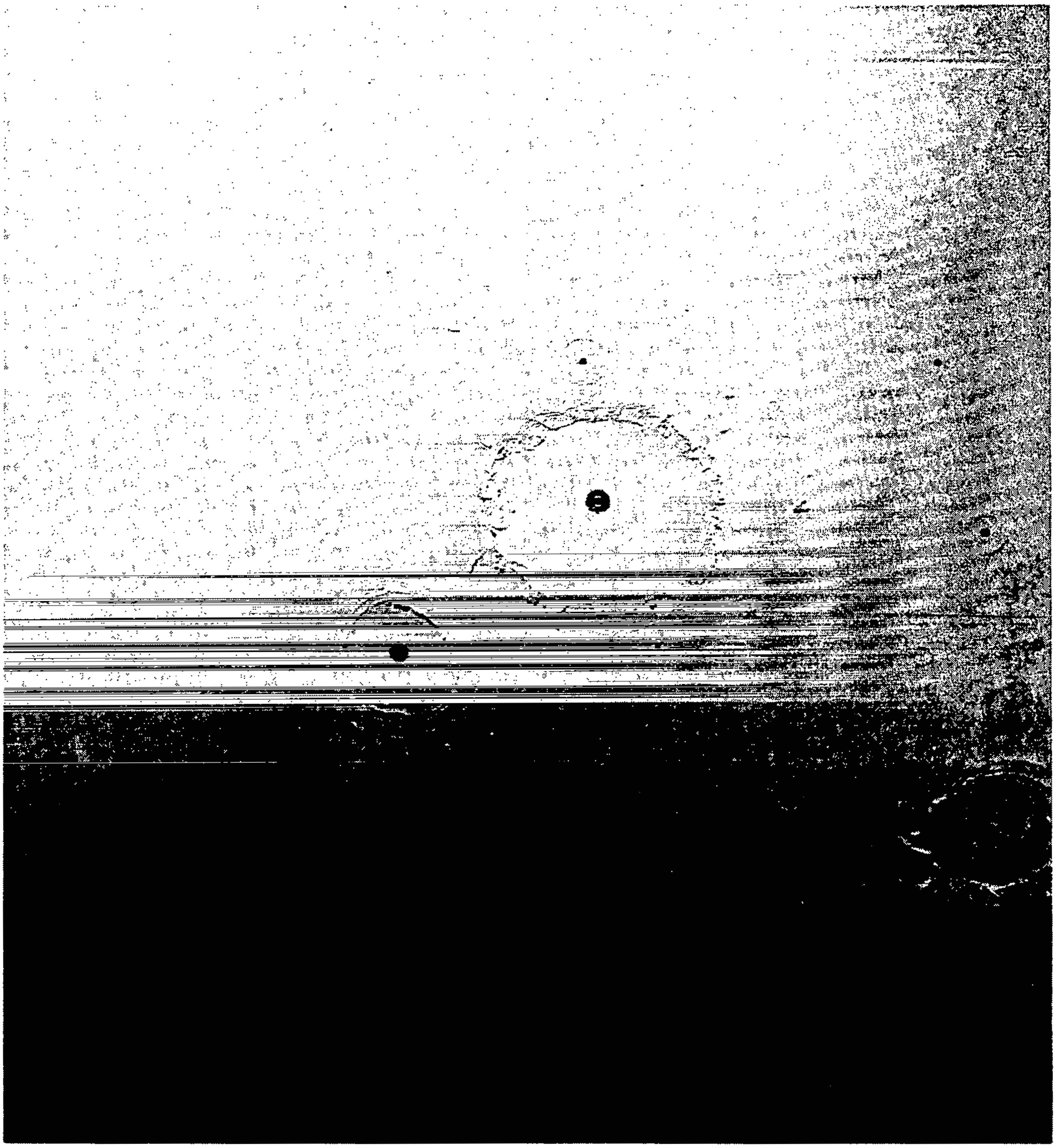
ACCOMPANYING FIGURES:

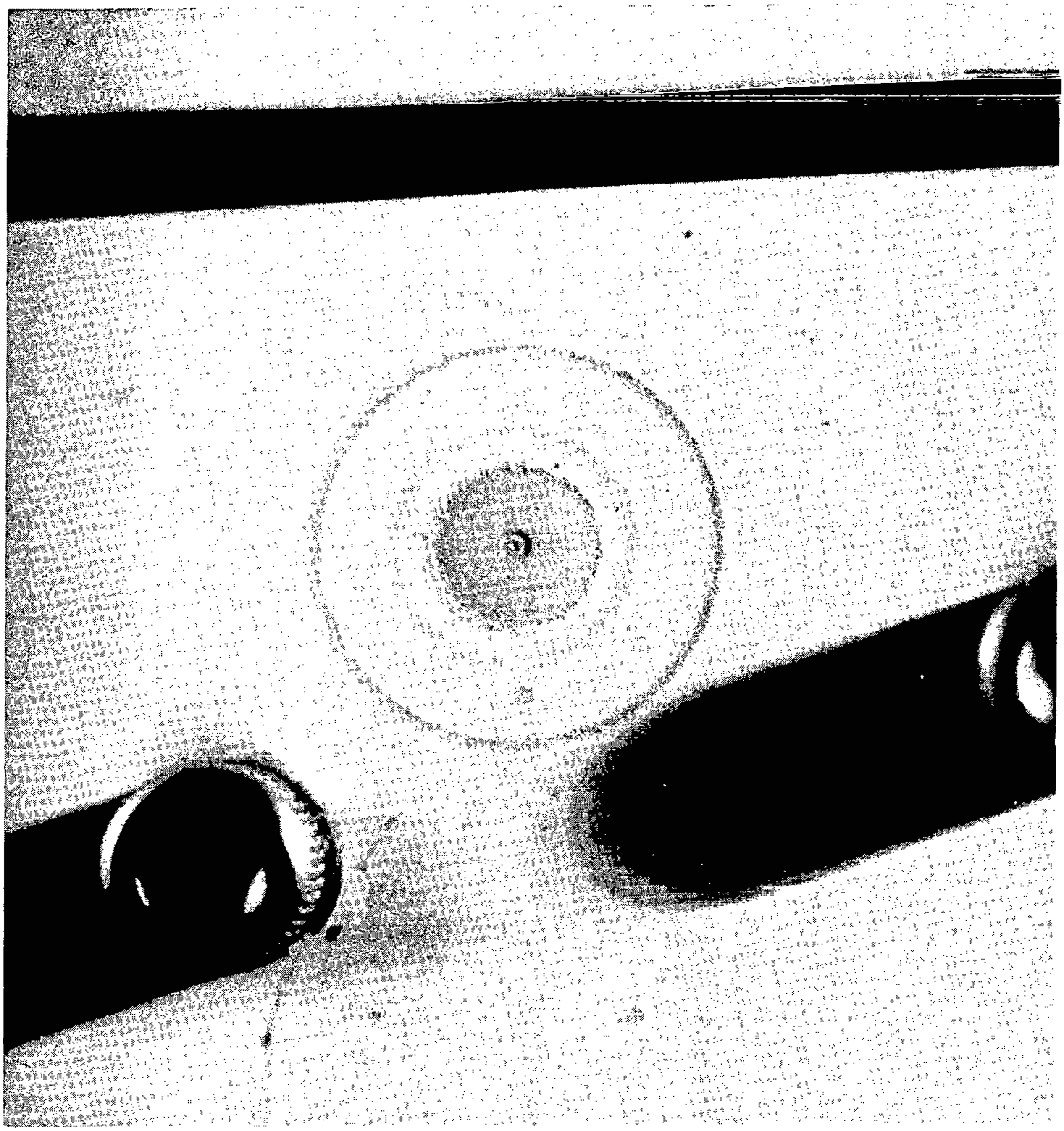
Figure F08-1. This post-deintegration view shows the front of the entire F08 experiment tray. Figures F08-2 and -3 detail impact features on the white-painted surface on the right third of the tray.

Figure F08-2. Impact features into the white-painted aluminum surface. Each crater extends through the paint into the aluminum substrate. Paint delamination features surround each impact. View measures approximately 8 cm across.

Figure F08-3. A concentrically-ringed impact feature into the white-painted aluminum surface. View measures approximately 4 cm across.







LDEF LOCATION: F09
EXPERIMENT IDENTIFICATION: A0076
EXPERIMENT TITLE: CASCADE VARIABLE-CONDUCTANCE HEAT PIPE
PRINCIPAL INVESTIGATOR: M. GROTE

MAIL CODE 1067307
MCDONNELL DOUGLAS ELECTRONIC SYSTEMS COMPANY
ST. LOUIS, MISSOURI 63166

SUMMARY OF OBSERVATIONS

Bay F09 is an active experiment tray which contained experiment A0076, the Cascade Variable-Conductance Heat Pipe. Experiment A0076 is a dry-reservoir variable-conductance heat pipe experiment designed to verify the capability of this type of thermal control system to provide precise temperature control of long-life spacecraft. The experiment occupied this 6"-deep (15.2 cm) peripheral tray and used two $LiSO_2$ batteries (one 7.5 volt and one 28 volt) for power. The experiment used the Experiment Power and Data System (EPDS) located in experiment S1001 (Bay F12) for data collection.

The A0076 experiment hardware consists of two series-connected variable-conductance heat pipes (internal to the experiment tray), covered by a multi-layer insulation (MLI) blanket of aluminized kapton sheets (Scheldahl G405120), each layer of which is separated by a polyester mesh. To opposite ends of the heat pipes are connected a heat absorber and a radiator. These are not covered by the MLI blanket and are exposed to space. The radiator is 316 stainless steel covered by a 0.005" (~0.13 mm) Type A Teflon, vacuum deposited Ag, vacuum deposited inconel, and silicon film (Scheldahl G401900). The heat absorber is painted black with Chemglaze Z-306 paint. The MLI blanket is attached to the experiment tray using Velcro G. In addition, the Principal Investigator allowed foil samples to be attached to the outside of the MLI blanket for space exposure.

The entire first layer of the MLI blanket was gone due to erosion by atomic oxygen exposure. The exposed foil samples remained attached only by the polyester mesh and were removed prior to blanket and tray removal from the spacecraft. These foils were provided to the M&D SIG A-Team, assigned component designation "E01", and surveyed for impacts. The Principal Investigator allowed the M&D SIG A-Team to core out small samples of these foils which contained ejecta spray and possible residue.

The remaining layers of the MLI blanket were removed from the experiment tray prior to the tray removal from LDEF. The blanket was not handled carefully after removal; it was folded up, placed in a plastic tub-type container, and provided to the M&D SIG A-Team. The M&D SIG A-Team spread the blanket flat again and, to facilitate shipping and minimize damage due to further handling, cut the blanket into seven pieces. The blanket sections were assigned component designations of: "E02" for section #2, "E03" for section #3, "E04" for section #4, "E05" for section #5, "E06" for section #6, "E07" for section #7, and "E08" for section #1. Due to an error by an M&D SIG A-Team member, component "E06" (section #6) was redesignated as "E09". To date, only three of these sections (E05, E08, and E09) have been surveyed for impacts. At the Principal Investigator's request, these three surveyed sections were returned to McDonnell Douglas.

All of the blanket sections, except #2 (E02), were marked with fiducial markings for reconstruction of blanket coordinates. The fiducial markings, coordinates, blanket section numbers are shown in the table below. An additional fiducial mark (#16) was made on section #7 (E07), but this mark came off the blanket when the washer and velcro fell off the blanket.

Bay F09 showed two primary types of impact morphology. Penetrations through one or more layers of the MLI blanket, with spray patterns on and subsequent penetrations through lower layers, were typical of hypervelocity penetrations through satellite shield bumpers and other MLI blankets (see Section 2.B.2.e. above). Impacts into metals were typical of craters produced during laboratory hypervelocity impact tests. For foil and blanket penetrations, the M&D SIG photodocumentation criteria is that the hole diameter must be larger than or equal to 0.3 mm.

On experiment tray F09, the M&D SIG survey visually identified a total of 388 impact features on all surveyed experiment and associated experiment-tray surfaces. These surfaces included the tray flanges and walls (0.125" [3.2 mm] thick chromic anodized 6061-T6 aluminum), the experiment-tray clamps (0.19" [4.8 mm] thick chromic anodized 6061-T6 aluminum), and the experiment-tray clamp bolts (303 stainless steel). The foils were not surveyed for impact features <0.3 mm in diameter.

On the experiment surfaces, 262 impacts were located. Of these, 58 were <0.3 mm in diameter in the foils and blanket (of which ten were photodocumented, and 14 were spray patterns only), and 107 were <0.5 mm in diameter in metal (two were photodocumented as they were considered to be of interest). In the foils and blanket, 46 of the impacts were between 0.3 mm and 1.0 mm in diameter, 13 were between 1.0 mm and 1.5 mm in diameter, one was between 1.5 mm and 2.0 mm in diameter, and nine were >2.0 mm in diameter. There was also one spray pattern >2.0 mm in diameter. On the metal experiment surfaces, 17 were between 0.5 mm and 1.0 mm in diameter, seven were between 1.0 mm and 1.5 mm in diameter, two were between 1.5 mm and 2.0 mm in diameter, and one was >2.0 mm in diameter.

Of the 86 impacts on the experiment-tray flanges and walls, 76 were <0.5 mm in diameter and were not photodocumented, eight were between 0.5 mm and 1.0 mm in diameter, and two were between 1.0 mm and 1.5 mm in diameter. On the experiment-tray clamps, 38 of the 40 impacts identified were <0.5 mm in diameter (of which one was photodocumented), and two were between 0.5 mm and 1.0 mm in diameter.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			58	58@
>0.3 mm			70	70@
<0.5 mm	38	76	107	221
>0.5 mm	2	10	27	39
TOTALS	40	86	262	388@

@ Survey for "Too Smalls" and impact features in foils and blanket was incomplete.

The largest impact features identified were (1) an ~2.8 mm diameter crater located on the radiator, (2) an ~4.1 x 5.0 mm diameter penetration in the MLI blanket, (3) an ~1.3 mm diameter penetration through a foil, (4) an ~1.3 mm diameter crater in the experiment-tray flanges, and (5) an ~0.8 mm crater on an experiment-tray clamp. A total of 122 features were photodocumented from tray F09.

The large penetration in the MLI blanket resembled the blast damage typical of a second layer blast loading after a hypervelocity penetration of a first layer. This would tend to indicate the original penetration occurred prior to the MLI's first layer being completely eroded. It is also possible that the penetration was widened due to atomic oxygen erosion after the initial penetration and the first layer erosion occurred.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment tray was mounted on the spacecraft. This inspection identified nine features which might be destroyed by attachment of the

experiment-tray cover and six features which would be destroyed by emplacement in the experiment-tray rotator. These latter impact features were estimated to be <0.5 mm in diameter. These features were not examined or photodocumented, nor were they included in the numerical summary given above. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges. One feature each was identified on clamps C01, C05, and C06, and two each were identified on clamps C03 and C04.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations or spallation features on the front or back of the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

The detailed examination and photodocumentation of tray F09 was conducted on March 27 and 28, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #1. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale. The foils were scanned using M&D SIG System #2, and the coordinates for features were measured with a metric scale. The three (of seven) MLI blanket sections were scanned using M&D SIG Systems #1 and #3, and the coordinates for features were measured with metric scales.

Bolt-Hole Registration (mm)

	TOP		BOTTOM	
	X	Y	X	Y
Far Left	61	959	59	-16
Center	620	957	617	-18
Far Right	1180	955	1176	-19

Blanket Section Fiducial Mark Locations (mm)

MARK NUMBER	X	Y	SECTION NUMBER
1	1020	4	1 (E08)
2	990	445	1 (E08)
3	433	4	3 (E03)
4	239	4	4 (E04)
5	45	5	4 (E04)
6	555	504	3 (E03)
7	349	539	6 (E09)
8	250	498	4 (E04)
9	54	544	7 (E07)
10	820	690	5 (E05)
11	818	890	5 (E05)
12	537	927	5 (E05)
13	346	854	6 (E09)
14	261	928	6 (E09)
15	66	855	7 (E07)

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC020001.F09	RC020001.F09	20	43		0.3	Al	*d*
LC040001.F09	RC040001.F09	25	75		0.5	Al	
LC060001.F09	RC060001.F09	100	7		0.8	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.F09	RE000001.F09	-2	868		0.7	Al	
LE000003.F09	RE000003.F09	358	968		0.6	Al	
LE000004.F09	RE000004.F09	761	953		1.3	Al	
LE000005.F09	RE000005.F09	1104	972		0.7	Al	
LE000006.F09	RE000006.F09	1186	960		1.1	Al	
LE000007.F09	RE000007.F09	1260	752		0.7	Al	
LE000037.F09	RE000037.F09	1230	-28		0.6	Al	*k*
LE000038.F09	RE000038.F09	1265	92		0.6	Al	
LE000039.F09	RE000039.F09	1266	243		0.6	Al	
LE000040.F09	RE000040.F09	1149	943	3	1.0	Al	*f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.F09	RE000002.F09	209	775		0.5	Al	*1*
LE000008.F09	RE000008.F09	931	840		0.3, 1.2, 2.5	Al	*2*
LE000009.F09	RE000009.F09	1029	866		0.2 x 0.4, 0.8, 2.1	Al	*2*
LE000010.F09	RE000010.F09	1023	898		0.3, 0.8, 4.6	Al	*2*
LE000011.F09	RE000011.F09	1052	873		0.4, 0.7, 2.3	Al	*2*
LE000012.F09	RE000012.F09	1098	890		0.5 x 0.6, 2.0, 4.7, 8.5	Al	*2*
LE000013.F09	RE000013.F09	1128	816		0.2, 1.1, 4.7	Al	*2*
LE000014.F09	RE000014.F09	924	755		0.2, 0.5, 2.0, 6.8	Al	*2*
LE000015.F09	RE000015.F09	956	753		0.3, 0.5, 2.4, 5.3	Al	*2*
LE000016.F09	RE000016.F09	998	754		ND, 0.5, 2.1, 4.3	Al	*2,j*
LE000017.F09	RE000017.F09	1174	756		0.5, 1.6, 4.0	Al	*2*
LE000018.F09	RE000018.F09	1185	764		0.4, 1.1, 2.6, 5.2	Al	*2*
LE000019.F09	RE000019.F09	855	712		0.2 x 0.3, 0.9, 2.2, 4.7	Al	*2*
LE000020.F09	RE000020.F09	890	690		0.2 x 0.3, 0.7	Al	*2,j*
LE000021.F09	RE000021.F09	1010	711		0.2, 0.7, 2.2, 4.2	Al	*2*
LE000022.F09	RE000022.F09	1003	661		0.3 x 0.4, 0.7, 2.2, 4.3	Al	*2*
LE000023.F09	RE000023.F09	1016	656		0.4, 0.6, 2.0, 4.4	Al	*2*
LE000024.F09	RE000024.F09	1101	636		ND, 0.7, 2.4, 4.8	Al	*2,j*
LE000025.F09	RE000025.F09	1195	603		0.3, 0.5, 2.0, 4.8	Al	*2*
LE000026.F09	RE000026.F09	1156	564		0.8, 2.8, 6.0, 11.0	Al	*2*
LE000027.F09	RE000027.F09	1105	587		0.5, 1.3, 3.1, 6.0	Al	*2*
LE000028.F09	RE000028.F09	1062	559		0.5, 1.1, 3.3, 12.0	Al	*2*
LE000029.F09	RE000029.F09	885	460		0.4, 0.9, 2.0, 5.3	Al	*2*
LE000030.F09	RE000030.F09	934	470		0.5, 0.7, 2.0, 5.2	Al	*2*
LE000031.F09	RE000031.F09	992	471		0.1, 0.5, 1.4, 3.7	Al	*2*
LE000032.F09	RE000032.F09	974	508		0.4, 0.7, 1.4, 4.6	Al	*2*
LE000033.F09	RE000033.F09	1066	510		0.4, 1.2, 3.2, 7.1	Al	*2*
LE000034.F09	RE000034.F09	317	627		0.6	Al	*1*
LE000035.F09	RE000035.F09	234	614		0.5 x 1.1	Al	*1,d*
LE000036.F09	RE000036.F09	71	694		0.8	Al	*1*
LE010001.F09	RE010001.F09	70	20		0.4	Al	*3*
LE010002.F09	RE010002.F09	130	22		0.5, 0.2	Al	*3,4,d,k*
LE010003.F09	RE010003.F09	190	21		0.4	Al	*3*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE010004.F09	RE010004.F09	185	23		0.2 x 0.3	Al	*3*
LE010005.F09	RE010005.F09	204	19		0.5	Al	*3*
AE010005.F09	BE010005.F09	204	19		0.5	Al	*3*
LE010006.F09	RE010006.F09	305	15		0.1	Al	*3,k*
LE010007.F09	RE010007.F09	15	160		1.3	Al	*3,k*
LE010008.F09	RE010008.F09	80	215		0.2	Al	*3,5,i*
LE010009.F09	RE010009.F09	93	230		0.3	Al	*3,5,i*
LE010010.F09	RE010010.F09	200	255		0.3	Al	*3*
LE010011.F09	RE010011.F09	160	240		0.2	Al	*3*
LE010012.F09	RE010012.F09	235	240		0.4	Al	*3*
LE010013.F09	RE010013.F09	190	280		0.2 x 1.2	Al	*3*
LE010014.F09	RE010014.F09	92	320		0.3	Al	*3,5,i*
LE010015.F09	RE010015.F09	100	310		0.3	Al	*3*
LE010016.F09	RE010016.F09	225	280		1.0	Al	*3,e*
LE010017.F09	RE010017.F09	226	277		1.0	Al	*3*
LE050001.F09	RE050001.F09	546	510		0.2, 1.7 x 2.0	MLI	*6,7,8,e*
LE050002.F09	RE050002.F09	572	512		0.3, 0.9 x 1.0	MLI	*6,7,8,e*
LE050003.F09	RE050003.F09	743	525		0.4	MLI	*6*
LE050004.F09	RE050004.F09	603	550		0.6 x 1.1	MLI	*6,e*
LE050005.F09	RE050005.F09	737	560		0.5 x 0.7	MLI	*6*
LE050006.F09	RE050006.F09	583	575		0.1 x 0.4, 0.5	MLI	*6,7,8,e*
LE050007.F09	RE050007.F09	654	585		1.2	MLI	*6,7,e*
LE050008.F09	RE050008.F09	673	590		0.8	MLI	*6*
LE050009.F09	RE050009.F09	598	630		0.4 x 1.1, 14.0	MLI	*6,7,8,e*
LE050010.F09	RE050010.F09	796	635		0.5	MLI	*6,e*
LE050011.F09	RE050011.F09	717	662		0.7	MLI	*6*
LE050012.F09	RE050012.F09	768	665		0.5	MLI	*6,7,e*
LE050013.F09	RE050013.F09	616	679		1.2	MLI	*6,9*
LE050014.F09	RE050014.F09	637	704		0.3	MLI	*6,e*
LE050015.F09	RE050015.F09	739	710		0.6	MLI	*6*
LE050016.F09	RE050016.F09	786	704		1.0, 1.3	MLI	*6,10,e*
AE050016.F09	BE050016.F09	786	704		1.0, 1.3	MLI	*6,10,e*
LE050017.F09	RE050017.F09	525	816		0.6, 0.5	MLI	*6,9,11*
LE050018.F09	RE050018.F09	802	838		0.5 x 1.4	MLI	*6,e*
LE050019.F09	RE050019.F09	587	847		4.1 x 5.0	MLI	*6,12*
LE050020.F09	RE050020.F09	784	851		0.8	MLI	*6*
LE050021.F09	RE050021.F09	678	927		0.4	MLI	*6*
LE050022.F09	RE050022.F09	730	937		0.5	MLI	*6*
LE080001.F09	RE080001.F09	1096	27		0.8	MLI	*13,e*
LE080002.F09	RE080002.F09	1133	22		3.2	MLI	*13*
LE080003.F09	RE080003.F09	1073	30		0.1 x 0.5	MLI	*13*
LE080004.F09	RE080004.F09	1017	31		0.3	MLI	*13*
LE080005.F09	RE080005.F09	980	49		0.3	MLI	*13*
LE080006.F09	RE080006.F09	1198	136		0.2, 0.7	MLI	*13,10,e*
LE080007.F09	RE080007.F09	1215	140		0.4	MLI	*13,e*
LE080008.F09	RE080008.F09	1114	143		1.6	MLI	*13,e*
LE080009.F09	RE080009.F09	1015	159		0.3 x 0.5	MLI	*13*
LE080010.F09	RE080010.F09	1119	169		2.9, 7.2	MLI	*13,8,e*
LE080011.F09	RE080011.F09	1188	176		0.4	MLI	*13*
LE080012.F09	RE080012.F09	1224	184		0.3, 1.8	MLI	*13,10,e*
LE080013.F09	RE080013.F09	1124	191		1.1, 4.2	MLI	*13,8,e*
LE080014.F09	RE080014.F09	1084	224		2.1, 4.5	MLI	*13,8,e*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE080015.F09	RE080015.F09	843	292		0.2, 1.1	MLI	*13,8,e*
LE080016.F09	RE080016.F09	1235	270		0.8, 2.1	MLI	*13,10,14,e*
LE080017.F09	RE080017.F09	1230	294		0.5, 1.8	MLI	*13,8,e*
LE080018.F09	RE080018.F09	1044	321		2.5, 4.4	MLI	*13,8,e*
LE080019.F09	RE080019.F09	986	349		4.2	MLI	*13,e*
LE080020.F09	RE080020.F09	1008	374		0.5, 1.8	MLI	*13,10,e*
LE080021.F09	RE080021.F09	1035	370		0.7, 1.1, 2.1	MLI	*13,15,e*
LE080022.F09	RE080022.F09	1033	400		1.4, 3.6	MLI	*13,8,e*
LE080023.F09	RE080023.F09	1220	404		0.4, 2.0	MLI	*13,10,e*
LE080024.F09	RE080024.F09	1157	413		1.5, 8.5	MLI	*13,10,e*
LE080025.F09	RE080025.F09	1183	435		0.2, 0.5, 2.8	MLI	*13,15,16,e*
LE080026.F09	RE080026.F09	1185	428		0.7 x 1.1, 1.6	MLI	*13,10,e*
LE080027.F09	RE080027.F09	1151	435		0.5 x 0.9, 8.0	MLI	*13,10,e*
LE080028.F09	RE080028.F09	1112	421		2.1, 5.6	MLI	*13,10,e*
LE090001.F09	RE090001.F09	378	553		0.7 x 1.3	MLI	*17*
LE090002.F09	RE090002.F09	379	560		0.8	MLI	*17*
LE090003.F09	RE090003.F09	473	533		0.9, 2.1	MLI	*17,8,e*
LE090004.F09	RE090004.F09	473	522		0.9, 3.4	MLI	*17,18*
LE090005.F09	RE090005.F09	481	563		0.4 x 0.5, 1.4	MLI	*17,18,e*
LE090006.F09	RE090006.F09	494	584		2.8 x 4.5, 7.0	MLI	*17,18,e*
LE090007.F09	RE090007.F09	374	794		0.8, 1.8	MLI	*17,10,e*
LE090008.F09	RE090008.F09	476	792		0.9, 4.4, 20.0	MLI	*17,19,e*
LE090009.F09	RE090009.F09	459	821		2.8, 6.3	MLI	*17,18,e*
LE090010.F09	RE090010.F09	411	854		3.5	MLI	*17,7,e*
LE090011.F09	RE090011.F09	277	863		0.5 x 0.7, 3.7	MLI	*17,18,e*
AE090012.F09	BE090012.F09	456	902		1.1, 2.8	MLI	*17,18*
LE090012.F09	RE090012.F09	456	902		1.1, 2.8	MLI	*17,18*
LE090013.F09	RE090013.F09	346	903		1.1, 2.5	MLI	*17,10,e*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined
MLI - Multi-Layer Insulation blanket

1 - Impact into black painted aluminum.
2 - Impact into silvered Teflon-covered aluminum radiator; diameters given are: (1) Ag/Al crater, (2) Teflon hole, (3) paint delamination, and (4) outer shock ring.
3 - Penetration into foils.
4 - Diameters after commas are diameters of penetrations through successive layers.
5 - Penetration from the rear.
6 - Impact into section 5 of the MLI blanket; this contains three fiducial markings (X, Y-coordinates from integrated blanket): #10 (820,690), #11 (818, 890), and #12 (537, 927).
7 - Spray due to penetration of upper layer.
8 - First diameter is diameter of tear due to blast loading from spray, second diameter is diameter of spray.
9 - Penetrations through multiple layers.
10 - First diameter is penetration diameter, second diameter is spray diameter.
11 - Wrong Y-coordinate (Y = 616) input into image file.
12 - Large blast damage zone with penetrations through multiple layers.
13 - Impact into section 1 of the MLI blanket; this contains two fiducial markings (X, Y-coordinates from integrated blanket): #1 (1020,4) and #2 (990, 445).

14 - Wrong coordinates (X = 1230, Y = 294) input into image file.
15 - Multiple holes in spray region; first two diameters are hole diameters, last diameter is spray diameter.
16 - Wrong coordinates (X = 1185, Y = 428) input into image file.
17 - Impact into section 6 of the MLI blanket; this contains three fiducial markings (X, Y-coordinates from integrated blanket): #7 (349,539), #13 (346, 854), and #14 (261,928).
18 - First diameter is penetration diameter, second diameter is tear length.
19 - First diameter is penetration diameter, second diameter is tear length, third diameter is spray diameter.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-383C-4425/3 through 108-KSC-383C-4425/7
On-Orbit - S32-78-087
Pre-Deintegration - KSC-390C-1030.05, KSC-390C-1030.06, KSC-390C-1030.12, KSC-390C-1031.02
Post Deintegration - KSC-390C-2157.03, KSC-390C-2364.02, KSC-390C-2364.09, KSC-390C-2365.11
M&D SIG Photos - None

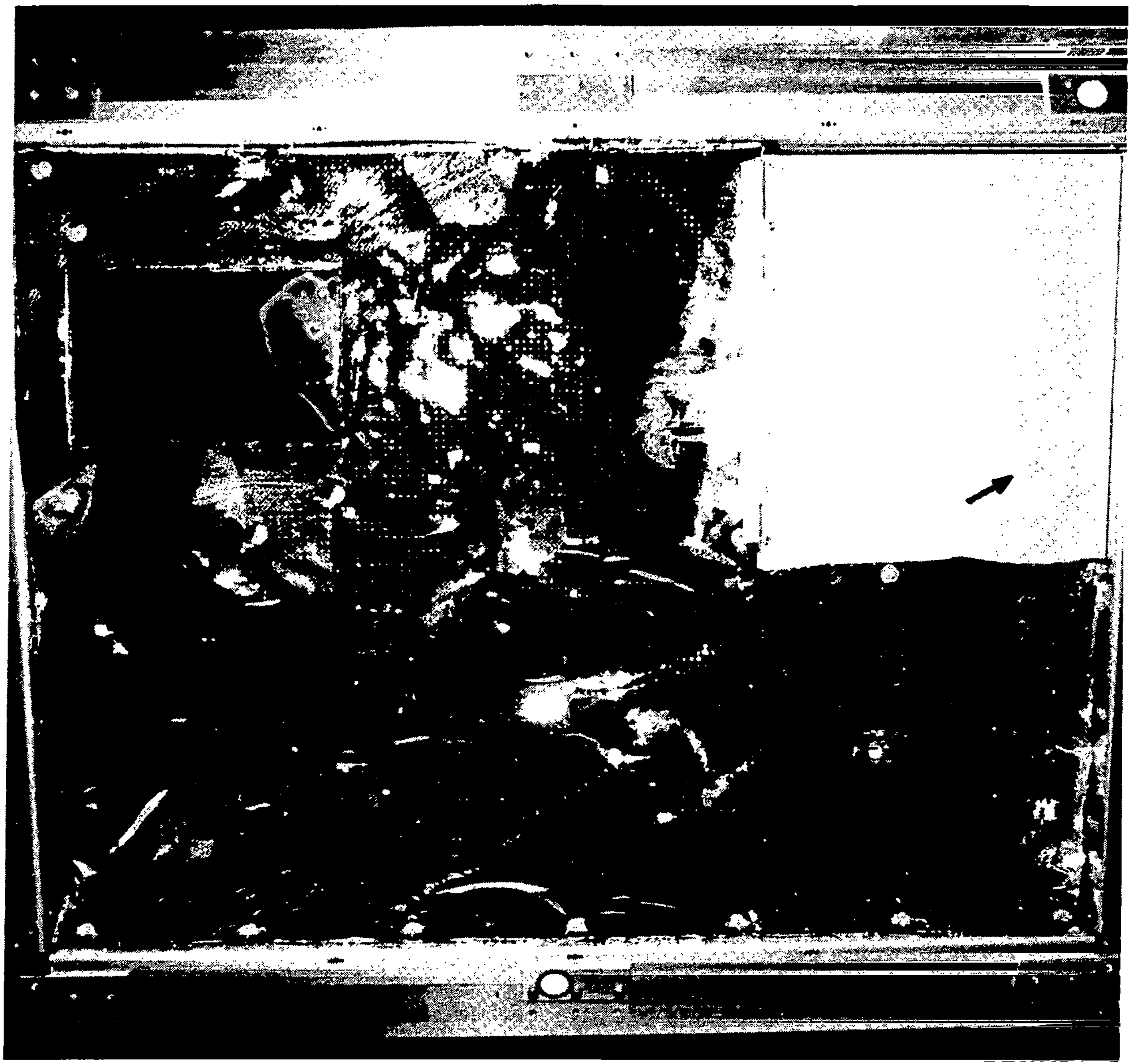
ARCHIVED MATERIALS:

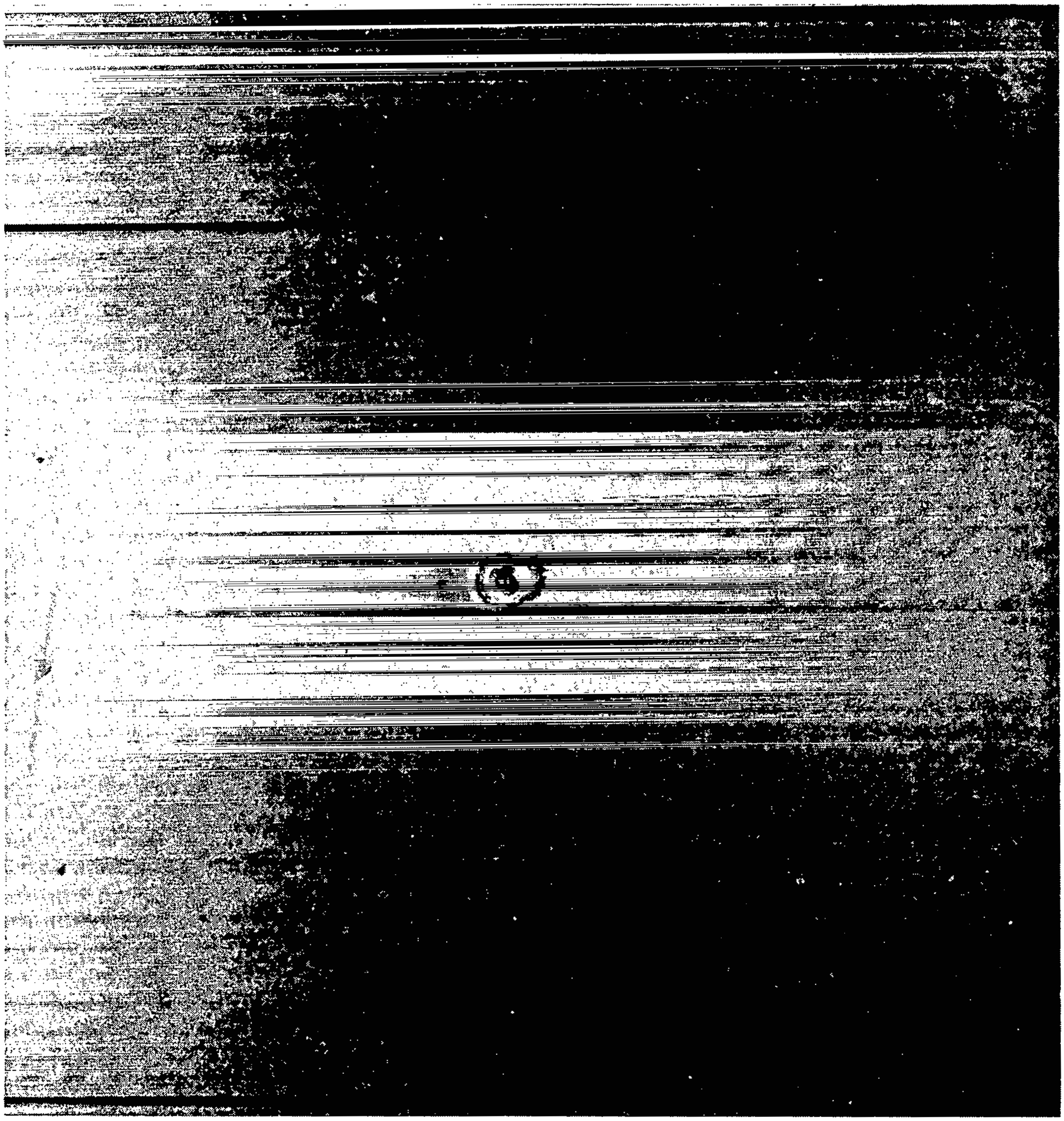
Clamps - F09C02, F09C03, F09C05, and F09C07
Clamp Bolts - F09S02A and F09S04C
Other - F09E02 - MLI Blanket Section #2
F09E03 - MLI Blanket Section #3
F09E04 - MLI Blanket Section #4
F09E07 - MLI Blanket Section #7
LD-33 - Core of Aluminum Tape (F09E00, 31, covered steel bolt)
LD-35 - Steel Bolt (F09E00, 31, located underneath aluminum tape)
LD-27 - Core of Aluminum-Mylar Foil (F09E01, 7)
LD-28 - Core of Aluminum-Mylar Foil, Feature #1 (F09E01, 16, layer #1)
LD-29 - Core of Aluminum-Mylar Foil, Feature #2 (F09E01, 16, layer #2)
LD-30 - Core of Aluminum-Mylar Foil, Feature #3 (F09E01, 16, layer #3)
LD-31 - Core of MLI Blanket Section #5 (F09E05, 19)
LD-36 - Core of MLI Blanket Section #1 (F09E08, 1)
LD-37 - Core of MLI Blanket Section #1 (F09E08, 2)
LD-38 - Core of MLI Blanket Section #1 (F09E08, 14)
LD-39 - Core of MLI Blanket Section #1 (F09E08, 24)
LD-86 - Core of MLI Blanket Section #1 (F09E08, 25)
LD-40 - Core of MLI Blanket Section #1 (F09E08, 27)

ACCOMPANYING FIGURES:

Figure F09-1. This pre-deintegration view shows the front of the entire F09 experiment tray, largely showing only the thermal blanket which remained once loosely-adhering foil samples had been removed. A arrow indicates the impact feature shown in Figure F09-2.

Figure F09-2. A concentrically-ringed impact feature into the white-painted aluminum surface. View measures approximately 8 cm across.





LDEF LOCATION: F10
EXPERIMENT IDENTIFICATION: S0001
EXPERIMENT TITLE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES
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SUMMARY OF OBSERVATIONS

Bay F10 is a passive experiment tray which is one of 25 whole or partial trays which make up the Space Debris Impact Experiment. The S0001 experiment hardware consists of aluminum plates (6061-T6 aluminum) each 0.1875" (4.8 mm) thick. The plates have a thin chromic anodized coating on both sides and a coat of Chemglaze Z306 black paint on the back side for thermal control. The S0001 experiment occupied nineteen 3"-deep (7.6 cm) peripheral trays, two 3"-deep (7.6 cm) end corner trays on the Earth-facing end of LDEF, and one 3"-deep (7.6 cm) end corner tray on the space-facing end of LDEF. Additionally, several partial tray locations on the periphery of LDEF were utilized and integrated with other experiments. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

On experiment tray F10, the M&D SIG survey visually identified a total of 77 impact features on all associated experiment-tray surfaces. However, a survey for impact features <0.5 mm was not conducted. In addition, due to time constraints, the experiment tray was only surveyed for impact features greater than or equal to 1.0 mm in diameter. The associated experiment-tray surfaces included the tray flanges and walls (0.0625" [1.6 mm] thick chromic anodized 6061-T6 aluminum), the experiment-tray clamps (0.19" [4.8 mm] thick chromic anodized 6061-T6 aluminum), and the experiment-tray clamp bolts (303 stainless steel). Thirty five of the impact features identified were <0.5 mm in diameter, but were not identified by location (*i.e.*, tray flanges or tray surface). On the experiment surface, 20 impacts were located. Of these, five were between 0.5 mm and 1.0 mm in diameter, ten were between 1.0 mm and 1.5 mm in diameter, two were between 1.5 mm and 2.0 mm in diameter, and three were >2.0 mm in diameter. Of the five impacts on the experiment-tray flanges and walls, 2 were between 0.5 mm and 1.0 mm in diameter, and three were between 1.5 mm and 2.0 mm in diameter. On the experiment-tray clamps, 13 of the 17 impacts identified were <0.5 mm in diameter, and the other four were between 0.5 mm and 1.0 mm in diameter. All features were typical of craters produced in aluminum during laboratory hypervelocity impact tests.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	13			48*@
>0.5 mm	4	5	20	29
TOTALS	17	5	20	77*@

* The location of the "Too Smalls" was not documented.
@ Survey for features <1.0 mm in diameter was incomplete.

The largest impact features identified were (1) an ~4.0 mm diameter crater located on the tray surface, (2) an ~1.2 mm diameter crater in the experiment-tray flanges, (3) an ~1.0 mm crater on an experiment-tray clamp, and (4) an ~0.3 mm crater on an experiment-tray clamp bolt. A total of 29 features were photodocumented from tray F10.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment tray was mounted on the spacecraft. This inspection identified two features which might be destroyed by attachment of the experiment-tray cover. In an effort to protect these features within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges. One impact was identified each on clamps C04 and C08.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.0625" (1.6 mm) thick experiment-tray flanges.

DOCUMENTATION:

The detailed examination and photodocumentation of tray F10 was conducted on March 2, 1990 in the horizontal position utilizing M&D SIG System #2. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3. The coordinates for all features were measured with a metric scale. Due to an error during imaging operations, all images of the integrated experiment tray taken with M&D SIG System #2 were mislabelled as LDEF location Bay F11.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC020001.F10	RC020001.F10	81	0		0.9	Al	
LC040001.F10	RC040001.F10	480	750		0.7	Al	
LC060001.F10	RC060001.F10	100	34		1.0	Al	
LC080001.F10	RC080001.F10	22	110		0.6	Al	
LS080001.F10	RS080001.F10	0	10		0.3	SS	*1*

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.F11	RE000001.F11	225	-45		1.0	Al	*2*
LE000002.F11	RE000002.F11	530	-39		0.6	Al	*2*
LE000003.F11	RE000003.F11	321	0	70	0.5	Al	*2,3,e,f,w*
LE000018.F11	RE000018.F11	1120	950		1.2	Al	*2*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000004.F11	RE000004.F11	23	177		0.7	Al	*2*
LE000005.F11	RE000005.F11	30	297		0.6	Al	*2*
LE000006.F11	RE000006.F11	86	97		0.6	Al	*2*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000007.F11	RE000007.F11	141	316		1.1	Al	*2*
LE000008.F11	RE000008.F11	156	322		0.6	Al	*2*
LE000009.F11	RE000009.F11	242	194		1.5	Al	*2*
LE000010.F11	RE000010.F11	292	12		0.9	Al	*2*
LE000011.F11	RE000011.F11	385	385		1.4	Al	*2*
LE000012.F11	RE000012.F11	416	75		1.3	Al	*2*
LE000013.F11	RE000013.F11	747	105		2.0	Al	*2*
LE000014.F11	RE000014.F11	964	126		1.1	Al	*2*
LE000015.F11	RE000015.F11	1049	95		1.3	Al	*2*
LE000016.F11	RE000016.F11	1049	95		1.3	Al	*2,4*
AE000016.F11	BE000016.F11	1224	333		2.0	Al	*2*
LE000017.F11	RE000017.F11	1190	470		1.5	Al	*2*
LE000019.F11	RE000019.F11	960	935		1.3	Al	*2*
LE000020.F11	RE000020.F11	830	710		4.0	Al	*2*
LE000021.F11	RE000021.F11	390	625		1.0	Al	*2,z*
LE000022.F11	RE000022.F11	640	880		1.3	Al	*2,z*
LE000023.F11	RE000023.F11	440	940		1.1	Al	*2,z*
LE000024.F11	RE000024.F11	210	510		1.2	Al	*2,z*
LE000025.F11	RE000025.F11	60	810		1.2	Al	*2,z*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

SS - 303 Stainless Steel

1 - Impact into bolt F10S08A.
2 - Image incorrectly labelled as experiment tray F11 instead of F10.
3 - Image taken at 45°above normal to crater.
4 - This image is actually of Feature #15, not Feature #16.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit
Pre-Deintegration - KSC-390C-1028.12, KSC-390C-1029.02 through KSC-390C-1029.05
Post Deintegration - KSC-390C-1655.07
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - F10C03, F10C05, F10C06, and F10C08
Clamp Bolts - F10S08A

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION: F11
TRAY IDENTIFICATION: S0001
EXPERIMENT PURPOSE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES
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HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Bay F11 held one of nineteen 3"-deep (7.6 cm), passive peripheral trays which were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 1/8" (3.2 mm) thick 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 126 features on the F11 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of the 126 impacts found, 57 were < 0.5 mm and were not imaged; the remaining 69 which were imaged included 61 which ranged in diameter between 0.3 mm and 0.5 mm, six between 1.0 mm and 1.5 mm, and two between 1.0 and 2.0 mm. Of the 57 impacts not imaged due to the impact size being less than the threshold limit of 0.5 mm, two were located on the tray flanges, 25 were located on the experimental tray surface, and 30 were located on tray-clamps (C01-C08). Of the 69 imaged impacts, ten were located on the tray flanges, nine were located on tray-clamps C01, C04, C06, C07, and C08, and the remaining 50 impacts were located on the aluminum tray surface. All features were typical of craters produced in aluminum during laboratory hypervelocity impact tests.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	30	2	25	57
>0.5 mm	9	10	50	69
TOTALS	39	12	75	126

The largest impact features identified on tray F11 were (1) a circular impact ~1.8 mm in diameter located on the tray surface, (2) a circular impact ~1.6 mm in diameter located on the tray flange, (3) a circular impact ~1.5 mm in diameter located on tray-clamp C04, and (4) an oblique impact 0.8 mm x 1.4 mm located on the tray surface. On the entire tray surface, and in many features, there was small thread-like debris which was either blue or white in color.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment tray was mounted on the spacecraft. The M&D SIG identified 11 features which might be damaged by the placement of the experiment-tray cover and seven additional features which could be damaged or destroyed by the placing of the experiment tray within the experiment-tray rotator stand. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from

coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations of the 0.0625" (1.6 mm) thick experiment-tray flanges and no bulges or spalls on the back of the tray flanges. There were strong discolorations on the side of the tray and discoloration under the crack between the plates on the frame.

DOCUMENTATION:

On March 5, 1990 the S0001 tray was inspected in the horizontal position using M&D SIG System #2. The detailed inspection of the clamps and bolts was performed on March 3, 1990, on M&D SIG System #3. Impact coordinates for all features were determined using a metric tape measure.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC010001.F11	RC010001.F11	41	1		0.4	Al	
LC040001.F11	RC040001.F11	44	48		0.6	Al	
LC040002.F11	RC040002.F11	43	51		1.6	Al	
LC060001.F11	RC060001.F11	102	43		0.3	Al	
LC060002.F11	RC060002.F11	111	38		0.3 x 0.5	Al	
LC070001.F11	RC070001.F11	23	12		1.1	Al	
LC070002.F11	RC070002.F11	40	41		0.7	Al	
LC070003.F11	RC070003.F11	49	47		0.4	Al	
LC080001.F11	RC080001.F11	47	60		0.4	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.F11	RE000001.F11	31	-7		0.7	Al	*1,10*
LE000005.F11	RE000005.F11	-30	125		0.7	Al	*10*
LE000030.F11	RE000030.F11	228	963		0.6	Al	*10,x*
LE000031.F11	RE000031.F11	283	986		0.7	Al	*2,10,x*
LE000032.F11	RE000032.F11	304	964		0.7	Al	*10,x*
LE000033.F11	RE000033.F11	850	-44		0.5	Al	*10*
LE000057.F11	RE000057.F11	1285	887		0.5	Al	*3,10*
LE000058.F11	RE000058.F11	1294	637		0.5	Al	*10*
LE000059.F11	RE000059.F11	1	270	24	0.5 x 1.7	Al	*4,10,d,f*
LE000060.F11	RE000060.F11	955	1	32	1.6	Al	*4,10,f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.F11	RE000002.F11	455	12		0.8 x 1.4	Al	*5,10*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000003.F11	RE000003.F11	675	25		0.7	Al	*10*
LE000004.F11	RE000004.F11	130	145		0.5	Al	*10*
LE000006.F11	RE000006.F11	565	290		0.7	Al	*6,10*
LE000007.F11	RE000007.F11	515	340		0.3 x 0.7	Al	*10*
LE000008.F11	RE000008.F11	490	350		0.6	Al	*10,k*
LE000009.F11	RE000009.F11	475	390		0.5	Al	*7,10*
LE000010.F11	RE000010.F11	515	475		0.5 x 0.6	Al	*7,10*
LE000011.F11	RE000011.F11	435	520		0.9	Al	*8,9,10,x*
LE000012.F11	RE000012.F11	370	555		0.9	Al	*10,x*
LE000013.F11	RE000013.F11	275	490		0.7	Al	*10,x*
LE000014.F11	RE000014.F11	185	515		0.8	Al	*10,x*
LE000015.F11	RE000015.F11	90	508		1.0	Al	*9,10,x*
LE000016.F11	RE000016.F11	140	580		0.7	Al	*10,x*
LE000017.F11	RE000017.F11	50	615		0.5	Al	*10,x*
LE000018.F11	RE000018.F11	345	569		1.0	Al	*10,x*
LE000019.F11	RE000019.F11	524	627		0.6	Al	*10,x*
LE000020.F11	RE000020.F11	434	665		0.6	Al	*10,x*
LE000021.F11	RE000021.F11	216	632		0.6	Al	*10,x*
LE000022.F11	RE000022.F11	223	651		1.2	Al	*10,x*
LE000023.F11	RE000023.F11	15	731		0.7 x 0.8	Al	*10,x*
LE000024.F11	RE000024.F11	-25	748		0.7	Al	*10,x*
LE000025.F11	RE000025.F11	207	747		1.2	Al	*10,x*
LE000026.F11	RE000026.F11	285	727		0.5	Al	*10,x*
LE000027.F11	RE000027.F11	202	775		0.5	Al	*10,x*
LE000028.F11	RE000028.F11	75	876		0.8	Al	*10,x*
LE000029.F11	RE000029.F11	357	859		0.6	Al	*10,x*
LE000034.F11	RE000034.F11	645	38		0.4 x 0.5	Al	*10*
LE000035.F11	RE000035.F11	632	152		0.6	Al	*10*
LE000036.F11	RE000036.F11	682	24		0.7	Al	*10*
LE000037.F11	RE000037.F11	774	281		0.5	Al	*10*
LE000038.F11	RE000038.F11	1110	41		0.5	Al	*10*
LE000039.F11	RE000039.F11	1050	204		1.2	Al	*3,10*
LE000040.F11	RE000040.F11	1138	225		0.6	Al	*10*
LE000041.F11	RE000041.F11	758	309		1.8	Al	*10*
LE000042.F11	RE000042.F11	810	316		0.7	Al	*10*
LE000043.F11	RE000043.F11	747	428		0.9	Al	*10*
LE000044.F11	RE000044.F11	800	394		0.8	Al	*3,10*
LE000045.F11	RE000045.F11	779	366		0.7	Al	*10*
LE000046.F11	RE000046.F11	1032	405		0.8	Al	*3,10*
LE000047.F11	RE000047.F11	1048	322		1.0 x 1.1	Al	*10*
LE000048.F11	RE000048.F11	1081	315		0.7	Al	*10*
LE000049.F11	RE000049.F11	664	759		0.7	Al	*10*
LE000050.F11	RE000050.F11	642	759		0.8	Al	*10*
LE000051.F11	RE000051.F11	697	640		0.5	Al	*10,w*
LE000052.F11	RE000052.F11	805	737		1.0	Al	*10*
LE000053.F11	RE000053.F11	860	810		0.6	Al	*10*
LE000054.F11	RE000054.F11	916	858		0.7	Al	*10*
LE000055.F11	RE000055.F11	1032	736		0.5	Al	*10*
LE000056.F11	RE000056.F11	1196	615		0.7	Al	*10*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Wrong coordinates (X=0, Y=0) stored with image file.
2 - Crater lip folded back.
3 - Thread-like debris in crater.
4 - Microscope at 35° angle to tray wall surface.
5 - Low velocity impact.
6 - Uneven crater lip.
7 - Slightly oblique impact.
8 - X and Y coordinates switched in image file, stored incorrectly as (X=520, Y=435).
9 - Crater lip torn and bent back.
10 - Left and Right images stored as experiment tray F10 instead of F11.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-78-56
Pre-deintegration - KSC-390C-1028.03, KSC-390C-1028.09, KSC-390C-1028.11
Post Deintegration - KSC-390C-1656.10
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - F11C02, F11C04, F11C06, and F11C07

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION:	**F12**
TRAY IDENTIFICATION:	**S1001**
EXPERIMENT TITLE:	**LOW TEMPERATURE HEAT PIPE EXPERIMENT FOR LDEF**
PRINCIPAL INVESTIGATOR:	**R. MCINTOSH, Jr.** **NASA GODDARD SPACE FLIGHT CENTER** **GREENBELT, MARYLAND**

SUMMARY OF OBSERVATIONS

Bay F12 was occupied by a 12"-deep (30.5 cm), active experiment tray which was one of two experiment trays comprising the S1001 experiment. The other tray was located in Bay H01 and was also an active tray. Tray F12 contained the hardware and the experiment power and data system (EPDS) for data collection and storage, where as tray H01 contained the Heat Pipe Experiment Package (HEPP) power supply, which consisted of an 8000 watt-hour nickel-cadmium (NiCd) battery and four solar arrays. Multi-layer Insulation Blankets (MLI) were employed, and a shielding configuration was developed to minimize parasitic inputs from the Earth and maximize radiation to deep space. Additionally, Kapton control samples were added to tray F12 as an atomic-oxygen coatings investigation to determine ways of protecting Kapton polyimide film from atomic-oxygen degradation. Several specimens (a Kapton control, Kapton with coatings of In_2O_3, urethane-acrylic, and silicones) were taped to Kapton film (14" square) using Kapton-backed pressure-sensitive tape. These samples were taped directly onto the Kapton thermal blanket covering tray F12.

Impacts into the Kapton blanket possessed large irregular entry diameters, with small central pits (measured as the feature diameter). The features penetrated the top layer of Kapton and usually possessed large spall zones which discolored the surface of the Kapton.

The MLI Kapton blanket was removed from Bay F12 by the Principal Investigator one month prior to tray removal from LDEF. The blanket was one of the first pieces of hardware removed from the satellite. The criteria for feature documentation for the blanket was penetrations greater than or equal to 0.3 mm in diameter. The Kapton blanket and experiment tray were documented using four different component designations: E01 was the large ~3' x 2' (~91 x 61 cm) Kapton blanket, E02 and E03 were small pieces of Kapton tape removed from the MLI blanket, and E00 was the interior of the experiment tray after the blanket was removed.

The M&D SIG survey identified a total of 196 features on the F12 experiment tray including the experiment-tray bolts, clamps, shims, and flanges as well as the Kapton MLI blanket and the interior experiment tray. Of the 196 impacts found, 114 were <0.5 mm in aluminum and were not imaged. Of these, 15 were located on the experiment-tray clamps, 32 were located on the experiment-tray flanges, and 67 were located on the experiment-tray surface after the MLI blanket was removed. Of the remaining 27 impacts in aluminum, one was located on experiment-tray clamp C03 and was ~0.8 mm in diameter, 11 were located on the experiment-tray flanges and ranged in diameter from 0.5 mm to 1.2 mm, and the remaining 14 were located on the tray surface with the MLI blanket removed and ranged in size from 0.5 mm to 1.7 mm in diameter. Thirty-nine impacts were located on the Kapton MLI blanket and ranged in size between 0.2 mm and 1.3 mm in diameter, and seven were located on the two pieces of Kapton tape and ranged in size from 0.2 mm to 1.0 mm in diameter. All features into aluminum were typical of craters produced in aluminum during laboratory hypervelocity impact tests.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			29	29
>0.3 mm			26	26
<0.5 mm	15	32	67	114
>0.5 mm	1	11	15	27
TOTALS	16	43	137	196

The largest impact features identified on tray F12 were 1) a circular impact ~1.2 mm in diameter located on the experiment-tray flange, 2) a circular impact ~0.8 mm in diameter located on the experiment-tray clamp C03, and 3) an oblique impact ~1.0 mm x 0.6 mm in diameter located on the Kapton MLI blanket.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 21, 1990 while the experiment tray was mounted on the spacecraft. The M&D SIG identified two features which might be damaged by the attachment of the experiment-tray cover and two additional features which could be damaged or destroyed by placing the experiment tray within the experiment-tray rotator stand. These latter features were not examined or documented, nor were they included in the numerical summary given above. In an effort to protect the more interesting features within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off for the experiment-tray cover and the tray flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations of the 0.125" (3.2 mm) thick experiment-tray flanges and no bulges or spalls on the back of the tray flanges.

DOCUMENTATION:

On February 21, 1990 the S1001 Kapton MLI blanket was inspected and photodocumented in the horizontal position by M&D SIG system #3 and impact coordinates were determined using a metric scale. The detailed inspection of the experiment-tray surface was conducted on March 28, 1990 in the vertical position using M&D SIG system #2 and Coordinate Registration System #2. The detailed inspection of the clamps and bolts was also performed on March 28, 1990, on M&D SIG System #3 and impact coordinates were determined using a small metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC030001.F12	RC030001.F12	125	47		0.8	Al	*1*

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.F12	RE000001.F12	222	951		0.5	Al	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.F12	RE000002.F12	280	945		0.7	Al	
LE000003.F12	RE000003.F12	416	950		0.6	Al	
LE000004.F12	RE000004.F12	580	945		0.5	Al	
LE000014.F12	RE000014.F12	-25	253		0.6	Al	
LE000015.F12	RE000015.F12	-40	307		0.8	Al	
LE000016.F12	RE000016.F12	266	-40		1.2	Al	*2*
LE000017.F12	RE000017.F12	1037	-20		0.6	Al	
LE000018.F12	RE000018.F12	1264	26		0.5 x 0.6	Al	*d*
LE000019.F12	RE000019.F12	1252	200		0.6	Al	
LE000026.F12	RE000026.F12	49	-5		1	Al	*3*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000005.F12	RE000005.F12	524	905		0.5	Kapton tape	*8*
LE000006.F12	RE000006.F12	400	778		0.7	Kapton tape	*8*
LE000007.F12	RE000007.F12	270	845		0.5	Kapton tape	*8*
LE000008.F12	RE000008.F12	95	795		0.5	Kapton tape	*8,d*
LE000009.F12	RE000009.F12	81	918		0.2	Kapton tape	*4,8*
LE000010.F12	RE000010.F12	155	430	230	1.5	Al	*5,8*
LE000011.F12	RE000011.F12	482	425	120	0.7	Al	*6,8*
LE000012.F12	RE000012.F12	575	585	50	0.7	Al	*7,8*
LE000013.F12	RE000013.F12	135	275	185	1.2	Al	*8*
LE000020.F12	RE000020.F12	625	170		0.7	Al	*8,k*
LE000021.F12	RE000021.F12	425	178		0.8 x 1.1	Al	*8*
LE000022.F12	RE000022.F12	398	147		1.1 x 1.7	Al	*8,k*
LE000023.F12	RE000023.F12	250	85		2.2	Al	*8*
LE000024.F12	RE000024.F12	141	70		0.5	Al	*8*
LE000025.F12	RE000025.F12	20	123		0.5	Al	*8*
LE010001.F12	RE010001.F12	34	600		0.2 x 0.3	Kapton	*9,z*
LE010002.F12	RE010002.F12	110	470		0.5	Kapton	*9,d,z*
LE010003.F12	RE010003.F12	140	530		0.6	Kapton	*9,d,z*
AE010003.F12	BE010003.F12	140	530		0.6	Kapton	*9,11,z*
LE010004.F12	RE010004.F12	200	510		0.2 x 0.3	Kapton	*9,12,z*
LE010005.F12	RE010005.F12	180	490		0.2 x 0.3	Kapton	*9,z*
LE010006.F12	RE010006.F12	470	520		0.7	Kapton	*9,z*
AE010006.F12	BE010006.F12	470	520		0.7	Kapton	*9,13,z*
LE010007.F12	RE010007.F12	120	310		0.3	Kapton	*9,z*
LE010008.F12	RE010008.F12	130	250		0.3 x 0.4	Kapton	*9,z*
LE010009.F12	RE010009.F12	140	270		0.1	Kapton	*9,d,k,z*
AE010009.F12	BE010009.F12	140	270		0.1	Kapton	*9,14,z*
LE010010.F12	RE010010.F12	160	290		0.4	Kapton	*9,z*
LE010011.F12	RE010011.F12	130	260		0.2	Kapton	*9,z*
LE010012.F12	RE010012.F12	145	265		0.3	Kapton	*9,15,z*
LE010013.F12	RE010013.F12	140	265		0.1 x 0.2	Kapton	*9,z*
LE010014.F12	RE010014.F12	278	385		0.3 x 0.4	Kapton	*9,z*
LE010015.F12	RE010015.F12	255	285		0.1 x 0.2	Kapton	*9,16,z*
LE010016.F12	RE010016.F12	255	282		ND	Kapton	*9,17,z*
LE010017.F12	RE010017.F12	255	282		0.4	Kapton	*9,18,z*
LE010018.F12	RE010018.F12	265	385		0.2 x 0.3	Kapton	*9,z*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE010019.F12	RE010019.F12	500	460		0.2	Kapton	*9,19,z*
LE010020.F12	RE010020.F12	535	460		0.3 x 0.4	Kapton	*9,20,z*
LE010021.F12	RE010021.F12	550	420		0.2	Kapton	*9,20,z*
LE010022.F12	RE010022.F12	560	410		0.3	Kapton	*9,20,z*
LE010023.F12	RE010023.F12	595	380		0.2	Kapton	*9,z*
LE010024.F12	RE010024.F12	520	355		0.3	Kapton	*9,z*
LE010025.F12	RE010025.F12	501	355		0.5	Kapton	*9,21,z*
LE010026.F12	RE010026.F12	542	204		0.4	Kapton	*9,20,22,z*
LE010027.F12	RE010027.F12	555	180		0.3	Kapton	*9,20,z*
LE010028.F12	RE010028.F12	543	104		0.3 x 0.4	Kapton	*9,z*
LE010029.F12	RE010029.F12	477	64		0.1 x 0.3	Kapton	*9,z*
LE010030.F12	RE010030.F12	400	47		0.3	Kapton	*9,z*
LE010031.F12	RE010031.F12	343	533		0.1 x 0.2	Kapton	*9,23,z*
LE010032.F12	RE010032.F12	326	55		0.3	Kapton	*9,z*
AE010032.F12	BE010032.F12	326	55		0.3	Kapton	*9,24,z*
LE010033.F12	RE010033.F12	73	50		0.1	Kapton	*9,k,z*
LE010034.F12	RE010034.F12	157	320		0.4	Kapton	*9,25,z*
LE010035.F12	RE010035.F12	442	368		0.7 x 1.0	Kapton	*9,z*
AE010035.F12	BE010035.F12	442	368		0.7 x 1.0	Kapton	*9,26,z*
LE010036.F12	RE010036.F12	468	310		0.3 x 0.4	Kapton	*9,z*
LE010037.F12	RE010037.F12	427	290		0.6 x 1.0	Kapton	*9,27,z*
LE010038.F12	RE010038.F12	458	227		1.3	Kapton	*9,28,z*
LE010039.F12	RE010039.F12	420	125		1.7 x 3.4	Kapton	*9,29,z*
AE010039.F12	BE010039.F12	420	125		0.1	Kapton	*9,30,z*
LE020001.F12	RE020001.F12	115	4		0.2	Tape	*10,33*
AE020001.F12	BE020001.F12	115	4		0.2	Tape	*10,31*
LE020002.F12	RE020002.F12	198	7		0.5 x 0.7	Tape	*10*
AE020002.F12	BE020002.F12	7	198		0.5 x 0.7	Tape	*10,31*
LE020003.F12	RE020003.F12	35	170		0.3	Tape	*10*
AE020003.F12	BE020003.F12	35	170		0.3	Tape	*10,31*
LE020004.F12	RE020004.F12	45	140		0.2	Tape	*10*
AE020004.F12	BE020004.F12	45	140		0.2	Tape	*10,31*
LE020005.F12	RE020005.F12	23	80		0.1	Tape	*10,32*
AE020005.F12	BE020005.F12	23	80		0.1	Tape	*10,31*
LE030001.F12	RE030001.F12	30	45		0.3	Tape	*10*
AE030001.F12	BE030001.F12	30	45		0.3	Tape	*10,31,33*
CE030001.F12	DE030001.F12	30	45		0.3	Tape	*10,31*
LE030002.F12	RE030002.F12	35	50		0.2	Tape	*10*
AE030002.F12	BE030002.F12	35	50		0.2	Tape	*10,31*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Feature on corner edge of clamp - slight angle in photo.
2 - Doublet feature, D2=0.5 mm.
3 - On tray lip through Kapton tape, photo taken at 13° off normal.
4 - Blast zone D=0.5 mm.
5 - Microscope angle 30° from normal.
6 - Spall zone D=1.2 mm.

7 - Spall zone D=1.1 mm.
8 - Feature located on tray surface with thermal blanket removed.
9 - Feature located on Kapton thermal blanket.
10 - Feature located on tape removed from thermal blanket.
11 - Lower magnification view to show petals and debris spray.
12 - Spray pattern at 4:00 position.
13 - Lower magnification view showing the blow back region.
14 - Higher magnification view to show debris in crater.
15 - Irregular spall pattern.
16 - Spray from this penetration, penetrated lower foil.
17 - Image of both upper foil penetration and lower foil spray pattern and penetration for size comparison.
18 - Spray pattern and irregular penetration form feature LE0100015.F12.
19 - Gas flow markings.
20 - Irregular penetration and gas flow pattern.
21 - Strange discoloration pattern.
22 - Slightly oblique feature, high raised lips.
23 - Blow back pattern.
24 - Large spallation pattern and blow back.
25 - Blow back through foil layer.
26 - Spray pattern extends to ~5.0 mm from edge of penetration.
27 - Caused by secondaries from foil penetration, irregular shape.
28 - Penetration through tape and foils, irregular.
29 - Photo of secondary spray with penetration.
30 - Penetration D=0.2 x 0.3 mm.
31 - Photo taken from backside of tape.
32 - Penetration with large spall zone.
33 - Lower magnification view.

OTHER PHOTODOCUMENTATION:

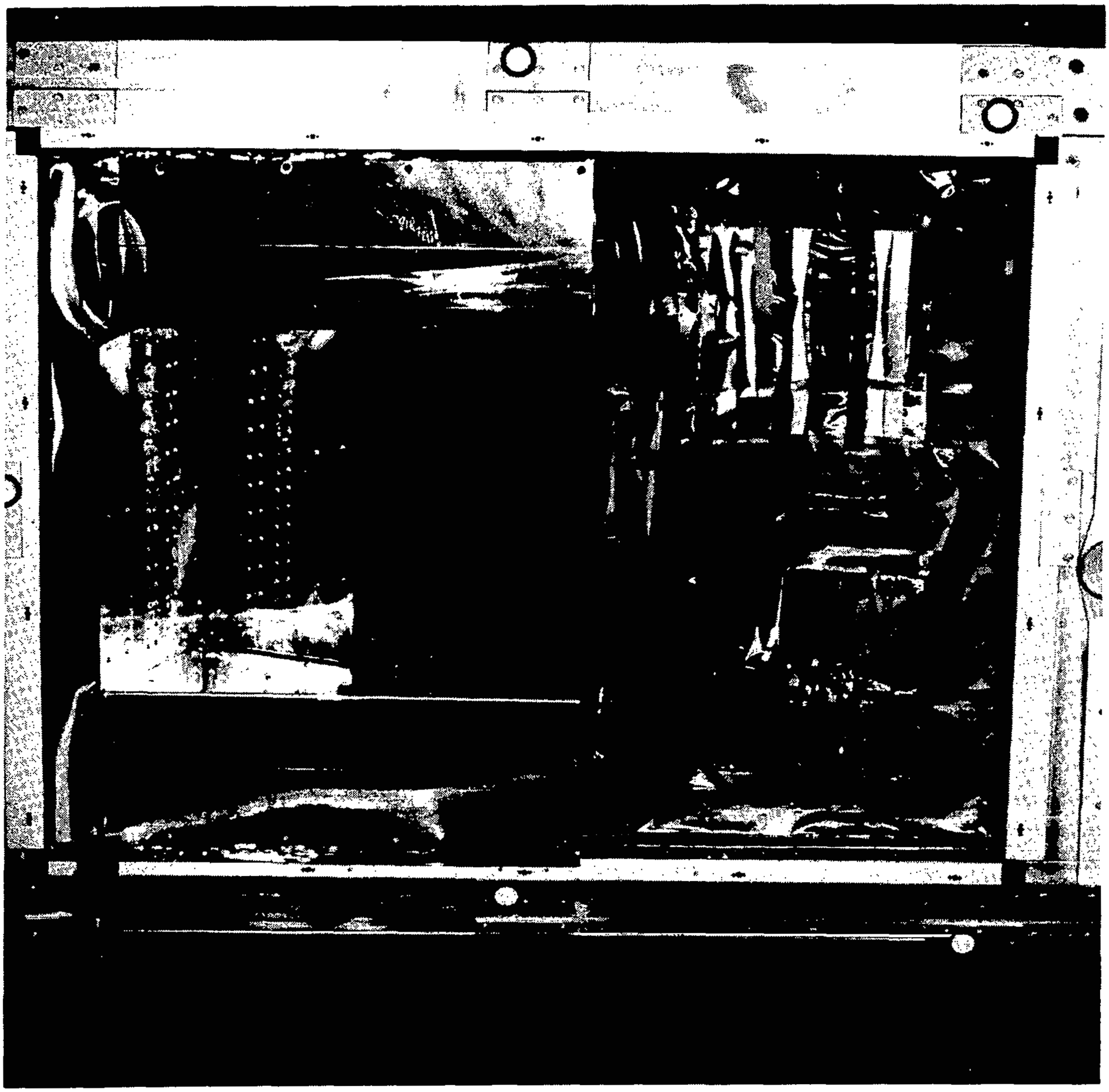
Pre-Flight - L-84-07339
On-Orbit - S32-89-057
Pre-deintegration - KSC-390C-1069.04, KSC-390C-1069.06 through KSC-390C-1069.08
Post Deintegration - KSC-390C-2429.04, KSC-390C-2429.05, KSC-390C-2368.11, KSC-390C-1069.08, KSC-390C-1191.01 through KSC-390C-1191.07, KSC-390C-1190.01 through KSC-390C-1190.12, KSC-390C-1212.01, KSC-390C-1212.07, KSC-390C-1212.08
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - F12C02, F12C04, F12C05, F12C07
Clamp Bolts - F12S04C, F12S07B
Clamp Shims - F12H01

ACCOMPANYING PHOTOS:

Figure F12-1. This pre-deintegration view shows the front of the entire F12 experiment tray. The aluminized-mylar thermal blanket on the right was removed before the tray was deintegrated.



LDEF LOCATION:	**G02**
EXPERIMENT IDENTIFICATION:	**A0015**
EXPERIMENT TITLE:	**FREE-FLYER BIOSTACK EXPERIMENT**
PRINCIPAL INVESTIGATOR:	**G. REITZ** **DFVLR** **INSTITUT FUR FLUGMEDIZIN** **ABTILUNG BIOPHYSIK** **LINDER HOHE, 5000 KOLN 90** **FEDERAL REPUBLIC OF GERMANY**

SUMMARY OF OBSERVATIONS

Bay G02 contained a 6"-deep (15.2 cm) passive Earth-end corner experiment tray which, together with the 1/3 partial tray in Bay C02, constituted the Free-Flyer Biostack Experiment (A0015). The experimental package was designed to expose biological specimens to the cosmic-ray particle (high atomic number [Z]/high energy) environment in low-Earth orbit to determine the importance, effectiveness, and hazards of the structured components of cosmic radiation to biological specimens and man. The total package exposed 20 detector units (12 in Bay G02) with variable shielding form the near-Earth space environment. Each detector was composed of a special sandwich construction of visual nuclear-track detectors and monolayers of biological specimens; the detector housings were constructed from chromic-anodized 2017 aluminum. The experiment base-support hardware consisted of chromic-anodized 2024 aluminum plates. Chemglaze Z306 black paint was used on the experiment back side for thermal control.

The M&D SIG survey only identified two impact features on all associated G02 experiment-tray surfaces including the experiment-tray flanges and walls (0.125" [3.2 mm] thick, chromic-anodized 6061-T6 aluminum), the experiment-tray clamps (0.18" [4.5 mm] thick, chromic-anodized 6061-T6 aluminum), and the experiment-tray clamp bolts (303 stainless steel). Both features were <0.5 mm in diameter and were located on the aluminum baseplate of the experiment; neither feature was photodocumented. However, both features were typical of craters found in similar materials which were produced under controlled laboratory conditions.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm			2	2
>0.5 mm				
TOTALS			2	2

The two identified features measured ~0.2 and ~0.3 mm in diameter. No features were imaged on this experiment tray.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 20, 1990 while the G02 experiment-tray was still mounted on the LDEF spacecraft. During this survey no features were identified which might be damaged or destroyed by deintegration activities or by securing the tray within the experiment-tray rotator.

GENERAL FRONT AND BACKSIDE:

The general front and backside inspections were performed on March 13, 1990 following the tray's removal from LDEF and prior to placing it within the experiment-tray rotator. There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

The detailed examination of the Bay G02 experiment tray was conducted on March 13, 1990 in the horizontal position utilizing M&D SIG System #3. The bolts, clamps, and shims associated with this tray were also scanned with M&D SIG System #3. The coordinates for all features were measured with either a metric tape measure or scale. No features were images on this experiment tray.

Bolt-Hole Registration - Not Determined

OTHER PHOTODOCUMENTATION:

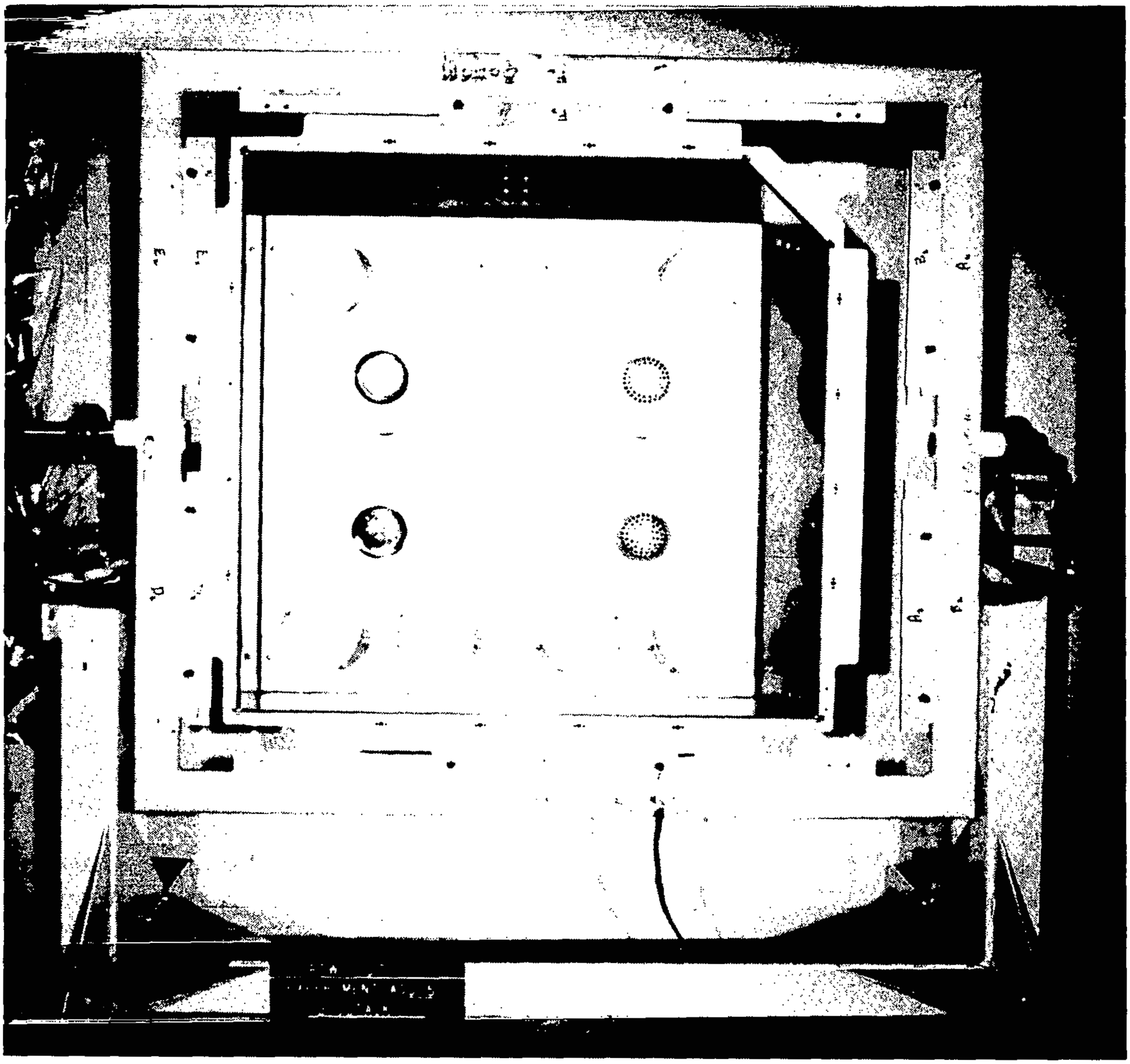
Pre-Flight - 108-KSC-384C-14/9
On-Orbit - S32-76-68
Pre-Deintegration - KSC-390C-1034.01, KSC-390C-833.03
Post Deintegration - KSC-390C-1928.07, KSC-390C-1938.08, KSC-390C-1938.09
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - G02C01, G02C02, G02C06, G02C07, G02C10, and G02C11

ACCOMPANYING FIGURES:

Figure G02-1. This post-deintegration view shows the front of the entire G02 experiment tray.



LDEF LOCATION: G03
EXPERIMENT TITLE: DUMMY PANEL
PRINCIPAL INVESTIGATOR: LDEF PROJECT OFFICE
NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23655-5225

SUMMARY OF OBSERVATIONS

Two so called "Dummy Panels" were flown on the Earth-facing end (G03 and G09) of LDEF the spacecraft. Each panel was fabricated from a 0.0625" (1.6 mm) thick sheet of chromic-anodized aluminum. Bays G03 and G09 were originally designed to hold experiment trays, but were not utilized because they were mostly blocked by the LDEF Walking Beam. Both panels were mounted flush with the spacecraft's structural frame and were held in place by twenty four 303 stainless steel bolts.

Detailed examination of Dummy Panel G03, and its associated bolts, by the M&D SIG A-Team identified seven impact features, all of which were <0.5 mm in diameter. Six of the seven features were located on various bolts, while the remaining feature, which was photodocumented, was located on the dummy-panel surface. None of the highly-oblique features observed by the M&D SIG A-Team on the black Earth-end thermal panels were discovered on the dummy panels at the Kennedy Space Center. However, a more detailed, microscopic examination of the dummy panels is being conducted at Langley Research Center in search of these highly-oblique features. Morphologically, all features examined on these panels were typical of craters produced in aluminum during controlled laboratory hypervelocity impact tests.

FEATURE SUMMARY

	BOLTS	DUMMY-PANEL SURFACE	TOTALS
<0.5 mm	6	1	7
>0.5 mm			
TOTALS	6	1	7

The largest impact features identified were (1) an ~0.3 x 0.4 mm diameter feature located on the dummy-panel surface and (2) an ~0.3 mm diameter feature on one of the stainless steel bolts.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The M&D SIG A-Team did not inspect Dummy Panel G03 prior to its removal from the spacecraft. However, there was no apparent damage noted on the impact features examined by the group following the panel's removal from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.0625" (1.6 mm) thick dummy panel.

DOCUMENTATION:

The detailed examination and photodocumentation of Dummy Panel G03 was conducted on February 6, 1990. The panel was examined and photodocumented in the horizontal position utilizing M&D SIG System #3. The coordinates for all features were measured with a metric tape measure. The associated bolts were

scanned utilizing M&D SIG System #2. The (0,0) reference point for both dummy panels was at the lower left-hand corner of the panel's left flange, where the top of the panel was defined as the edge toward Row 12.

Impact Features Imaged on Exposed Dummy Panel Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.G03	RE000001.G03	603	275		0.3 x 0.4	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration
M&D SIG Photos - None

ARCHIVED MATERIALS:

Dummy-Panel Bolt - G03S01

LDEF LOCATION: G04
EXPERIMENT IDENTIFICATION: S0001
EXPERIMENT TITLE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES
493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665-5225

SUMMARY OF OBSERVATIONS

Bay G04 held one of nineteen 3"-deep (7.6 cm), passive peripheral experiment trays that were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 0.125" (3.2 mm) thick, 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 19 features on the G04 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of these, 17 features from all surfaces were found to be smaller in diameter than the 0.5 mm photodocumentation threshold. Two of these 17 features were located on the experiment-tray clamps, 14 were located on the experiment-tray flanges (two of which were photodocumented at the request of the experiment PI), and one was located on the aluminum experimental surfaces. Of the remaining two features which were photodocumented, one (~0.6 mm in diameter) was on the aluminum collector surfaces and one (~0.5 mm in diameter) was on the inner wall of the top experiment-tray flange. All features exhibited characteristics typical of craters formed in aluminum during controlled laboratory hypervelocity impact experiments.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	2	14	1	17
>0.5 mm		1	1	2
TOTALS	2	15	2	19

The largest impact feature found on this tray measured ~0.6 mm in diameter and was located on the aluminum S0001 experimental surface.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

An initial inspection of the Bay G04 tray was performed on February 22, 1990 in order to document features which might be altered during tray deintegration activities. No such features were located.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick, chromic-anodized 6061-T6 experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of the Bay G04 experiment tray was conducted on March 23, 1990 in the vertical position utilizing M&D SIG System #3. Examination of the clamps, bolts, and shims was conducted on March 23, 1990 using M&D SIG System #2; the coordinates for all G04 experiment-tray hardware were measured with a small metric tape measure.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.G04	RE000002.G04	755	475	55	0.5	Al	
LE000003.G04	RE000003.G04	760	605	35	0.3	Al	
LE000004.G04	RE000004.G04	0	568	58	0.4	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.G04	RE000001.G04	320	258		0.6	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit
Pre-Deintegration - KSC-390C-1034.03
Post Deintegration - KSC-390C-2309.10, KSC-390C-2309.11
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - G04C03, G04C04, G04C06, G04C07, G04C09, and G04C12.

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION: G06
EXPERIMENT IDENTIFICATION: A0139A
EXPERIMENT TITLE: GROWTH OF CRYSTALS FROM SOLUTIONS IN LOW GRAVITY
PRINCIPAL INVESTIGATOR:
M. LIND
ROCKWELL INTERNATIONAL CORPORATION
P.O. BOX 1085
THOUSAND OAKS, CALIFORNIA 91360

SUMMARY OF OBSERVATIONS

Bay G06 was occupied by an active, 12"-deep (30.5 cm) experiment tray containing the Growth of Crystal From Solutions in Low Gravity experiment (A0139A). The goal of this experiment was to develop a novel solute-diffusion method for growing single crystals. Experimentally, the system was composed of several crystal-growth reactors which were equipped with mechanisms for automatically opening valves to initiate the diffusion and growth process. Power for the reactors was provided by $LiSO_2$ batteries. The various reactors were enclosed within a vacuum-tight container that was surrounded by thermal insulation. The entire tray was covered by a 0.0625" (1.6 mm) thick, 6061-T6 aluminum thermal cover which had been painted white. The rough texture of this painted surface made it difficult to visually identify impact features smaller than ~0.1 mm in size.

There were a total of eight features visually identified on the G06 surfaces, including the experiment-tray flanges and clamps, and the aluminum thermal cover of the experimental package. Four of these features were located on the experiment-tray flanges, one each on clamp C08 and C09, and two were found in the painted aluminum thermal cover. One of the features (~0.3 mm in diameter) on the experiment-tray flange, which was identified during the pre-deintegration inspection of the Bay G06 tray, could not be examined during the detailed inspection because it was covered by the experiment-tray rotator clamping mechanism. The only imaged feature was located on the thermal cover and measured ~0.3 mm in diameter. The few features that were identified in the painted- and unpainted aluminum surfaces were typical of craters produced in similar materials under controlled laboratory conditions, including the presence of the impact-induced spall zones around features located in painted surfaces.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	2	4	2	8
>0.5 mm				
TOTALS	2	4	2	8

The largest impact feature on this tray was the ~0.3 mm diameter feature mentioned above.

M&D SIG INSPECTIONS

PRE-DEINTEGRATION:

The initial inspection of the G06 experiment-tray was conducted on February 22, 1990 while the tray was mounted on the spacecraft. One feature (~0.3 mm in diameter) was identified on the upper-right experiment-tray flange which would be covered by the experiment-tray rotator clamping mechanism. Two additional

features (one each on clamps C08 and C09) were identified during this inspection, but neither were in areas which required the use of special tools or handling during the tray deintegration operations.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (3.2 mm) thick, chromic-anodized 6061-T6 experiment-tray flanges.

DOCUMENTATION:

Tray G06 was inspected in the vertical position with M&D SIG System #2 on March 7, 1990. Coordinates for photodocumented features were determined using a metric tape measure. A non-standard (0,0) reference point was assigned to this tray (*i.e.*, the lower left corner of the painted thermal cover was used as the [0,0] reference point instead of the bottom of the left experiment-tray flange; see Section 2.C.6.a). The tray clamps, bolts, and shims were scanned with M&D SIG System #3 on March 7, 1990, but no images were taken.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.G06	RE000001.G06	145	76		0.3	Al (painted)	*b*
AE000001.G06	BE000001.G06	145	76		0.3	Al (painted)	*1,b*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Higher magnification view.

OTHER PHOTODOCUMENTATION:

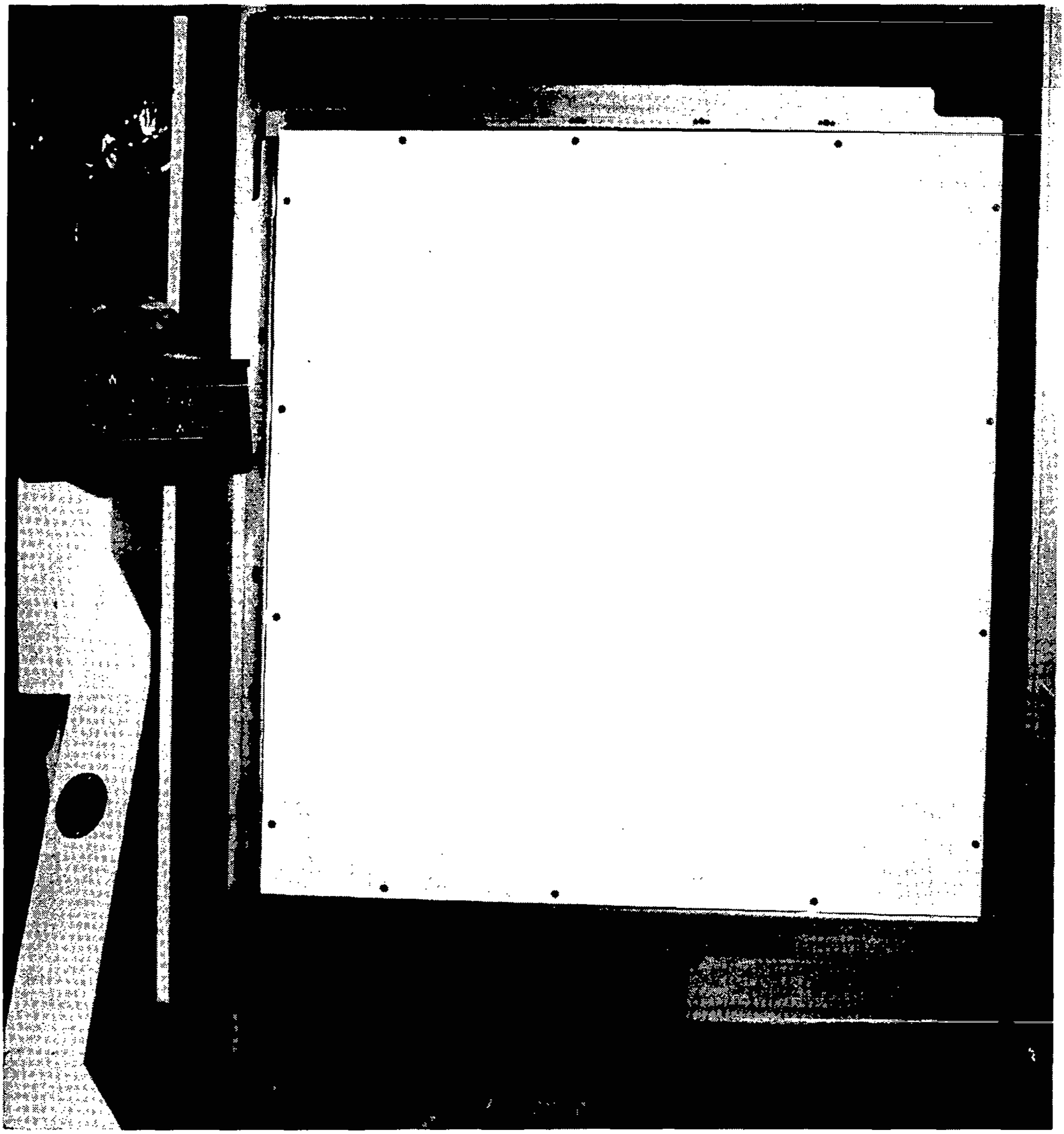
Pre-Flight - 108-KSC-384C-256/2
On-Orbit - S32-76-66
Pre-Deintegration - KSC-390C-1034.04
Post Deintegration - KSC-390C-1704.05
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - G06C06, G06C07, G06C09, G06C011, and G06C012
Clamp Bolts - G06S04A

ACCOMPANYING FIGURES:

Figure G06-1. This post-deintegration view shows the front of the entire G06 experiment tray.



LDEF LOCATION: G08
TRAY IDENTIFICATION: S0001
EXPERIMENT PURPOSE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES

493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23655-5225

SUMMARY OF OBSERVATIONS:

Bay G08 held one of nineteen 3"-deep (7.6 cm), passive peripheral experiment trays that were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 0.125" (3.2 mm) thick, 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified a total of 41 features on the G08 experiment tray including the experiment-tray bolts, clamps, shims, and flanges, as well as the 6061-T6 aluminum detector surfaces. Of the 41 features identified, 40 were <0.5 mm in diameter and were not imaged, the remaining feature (~0.3 mm in diameter) was located on the inner wall of the bottom experiment-tray flange. Of the 40 features, 31 were located on the aluminum experimental surface, six were located on the experiment-tray flanges, and three were identified on the experiment-tray clamps and bolts. All features were typical of craters produced in similar materials under controlled laboratory hypervelocity impact tests.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	3	6	32	41
>0.5 mm				
TOTALS	3	6	32	41

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection was conducted on February 22, 1990, while the experiment-tray was mounted on the spacecraft. This inspection did not identified any features which might be damaged by the experiment-tray cover or by the placement of the experiment tray within the experiment-tray rotator.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick, chromic-anodized 6061-T6 experiment-tray flanges. The inspection of the back surface of this tray did reveal some outgassing shadows on the black aluminum surface.

DOCUMENTATION:

On March 23, 1990 the G08 tray was inspected in the horizontal position utilizing M&D SIG System #3; the coordinates for all features were determined using a metric tape measure. The inspection of the experiment-tray clamps, bolts, and shims was conducted on March 26, 1990 with M&D SIG System #2.

Bolt-hole Registration - Not Determined

Impact Features Imaged on Experimental-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.G08	RE000001.G08	408	0	10	0.3	Al	*1,f*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Image taken at ~45° from normal of crater.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-76-77
Pre-deintegration - KSC-390C-1029.12
Post Deintegration - KSC-390C-2308.09
M&D SIG Photos - None

ARCHIVED MATERIALS

Clamps - G08C01, G08C03, G08C04, G08C10, G08C11, and G08C12

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION: G09
EXPERIMENT TITLE: DUMMY PANEL
PRINCIPAL INVESTIGATOR: LDEF PROJECT OFFICE
NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23655-5225

SUMMARY OF OBSERVATIONS

Two so called "Dummy Panels" were flown on the Earth-facing end (G03 and G09) of LDEF the spacecraft. Each panel was fabricated from a 0.0625" (1.6 mm) thick sheet of chromic-anodized aluminum. Bays G03 and G09 were originally designed to hold experiment trays, but were not utilized because they were mostly blocked by the LDEF Walking Beam. Both panels were mounted flush with the spacecraft's structural frame and were held in place by twenty four 303 stainless steel bolts.

Detailed examination of Dummy Panel G09, and its associated bolts, by the M&D SIG A-Team identified three impact features, all of which were <0.5 mm in diameter. Two of the three features were on the dummy-panel surface and were photodocumented, while the remaining feature was located on one of the dummy-panel bolts. None of the highly-oblique features observed by the M&D SIG A-Team on the black Earth-end thermal panels were discovered on the dummy panels at the Kennedy Space Center. A more detailed, microscopic examination of the dummy panels is being conducted at Langley Research Center in search of highly-oblique features. Morphologically, all features examined on these panels were typical of craters produced in aluminum during controlled laboratory hypervelocity impact tests.

FEATURE SUMMARY

	BOLTS	DUMMY-PANEL SURFACE	TOTALS
<0.5 mm	1	2	3
>0.5 mm			
TOTALS	1	2	3

The largest impact features identified were (1) an ~0.4 mm diameter feature located on the dummy-panel surface and (2) an ~0.3 mm diameter feature on one of the stainless steel bolts.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The M&D SIG A-Team did not inspect Dummy Panel G03 prior to its removal from the spacecraft. However, there was no apparent damage noted on the impact features examined by the group following the panel's removal from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.0625" (1.6 mm) thick dummy panel.

DOCUMENTATION:

The detailed examination and photodocumentation of Dummy Panel G09 was conducted on February 6, 1990. The panel was examined and photodocumented in the horizontal position utilizing M&D SIG System #3. The coordinates of features were measured with a metric tape measure. The (0,0) reference point for both

dummy panels was at the lower left-hand corner of the panel's left flange, where the top of the panel was defined as the edge toward Row 12.

Impact Features Imaged on Exposed Dummy Panel Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.G09	RE000001.G09	345	-113		0.4	Al	
LE000002.G09	RE000002.G09	882	409		0.3	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration
M&D SIG Photos - None

ARCHIVED MATERIALS:

None

LDEF LOCATION:	**G10**
EXPERIMENT IDENTIFICATION:	**A0201**
EXPERIMENT TITLE:	**INTERPLANETARY DUST EXPERIMENT**
PRINCIPAL INVESTIGATOR:	**G. WEINBURG** **INSTITUTE FOR SPACE SCIENCES AND TECHNOLOGY** **GAINESVILLE, FLORIDA 32609**

SUMMARY OF OBSERVATIONS

Bay G10 accommodated a 3"-deep (7.6 cm) experiment tray that was occupied by the metal-oxide-silicon (MOS), capacitor-type detectors of the A0201 Interplanetary Dust Experiment. Other bays, occupied in whole or part by the Interplanetary Dust Experiment, include Bays B12, C03, C09, D06, and H11. The goal of the MOS detectors was to obtain mass and velocity information on the particles impinging upon their surfaces. Two varieties of detectors totaling ~1 m^2 of exposed surface area were flown on A0201; sixty percent of the detector surfaces possessed an oxide coating of 0.4 μm thick, while the remaining 40 percent had a 1.0 μm thick oxide coating. Each one-third tray typically contained 80 MOS detectors and one Sun sensor.

Features examined within the originally smooth metal-oxide-silicon surfaces exhibited somewhat complex morphologies. Generally, these features exhibited a deep central pit; it was the diameter of this pit which was utilized by the M&D SIG A-Team for the 0.5 mm threshold criteria. Surrounding the central pits were spall zones possessing diameters on the order of 1.25 to 3 times that of the central pit. Fractures or cracks radiating from the central pit/spall zone were commonly found in association with the larger impacts into the amorphous metal-oxide-silicon material. All other features on this tray occurred in aluminum substrates and exhibited morphologic characteristics typical of craters in similar material produced under controlled laboratory hypervelocity impacts tests.

Detailed examination of the G10 experiment tray by the M&D SIG revealed a total of 27 features on all surfaces associated with the tray, 26 of which were <0.5 mm in diameter and were not photodocumented. The one feature that was photodocumented measured ~0.5 mm in diameter and was located on an experiment-tray flange. The distribution (between the experiment-tray flanges and the MOS/aluminum experimental surfaces) of the <0.5 mm features was not recorded.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm				26*
≥0.5 mm		1		1
TOTALS				27

* The locations of the "Too Smalls" were not documented.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection of the G10 experiment-tray was conducted on February 22, 1990 while the tray was mounted on the spacecraft. No features were identified on any of the hardware associated with this tray.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick, chromic-anodized 6061-T6 experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of the Bay G10 experiment tray was conducted on March 16, 1990 in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #2. The bolts, clamps, and shims associated with this tray were scanned with M&D SIG System #3.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.G10	RE000001.G10	21	200		0.5	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

OTHER PHOTODOCUMENTATION:

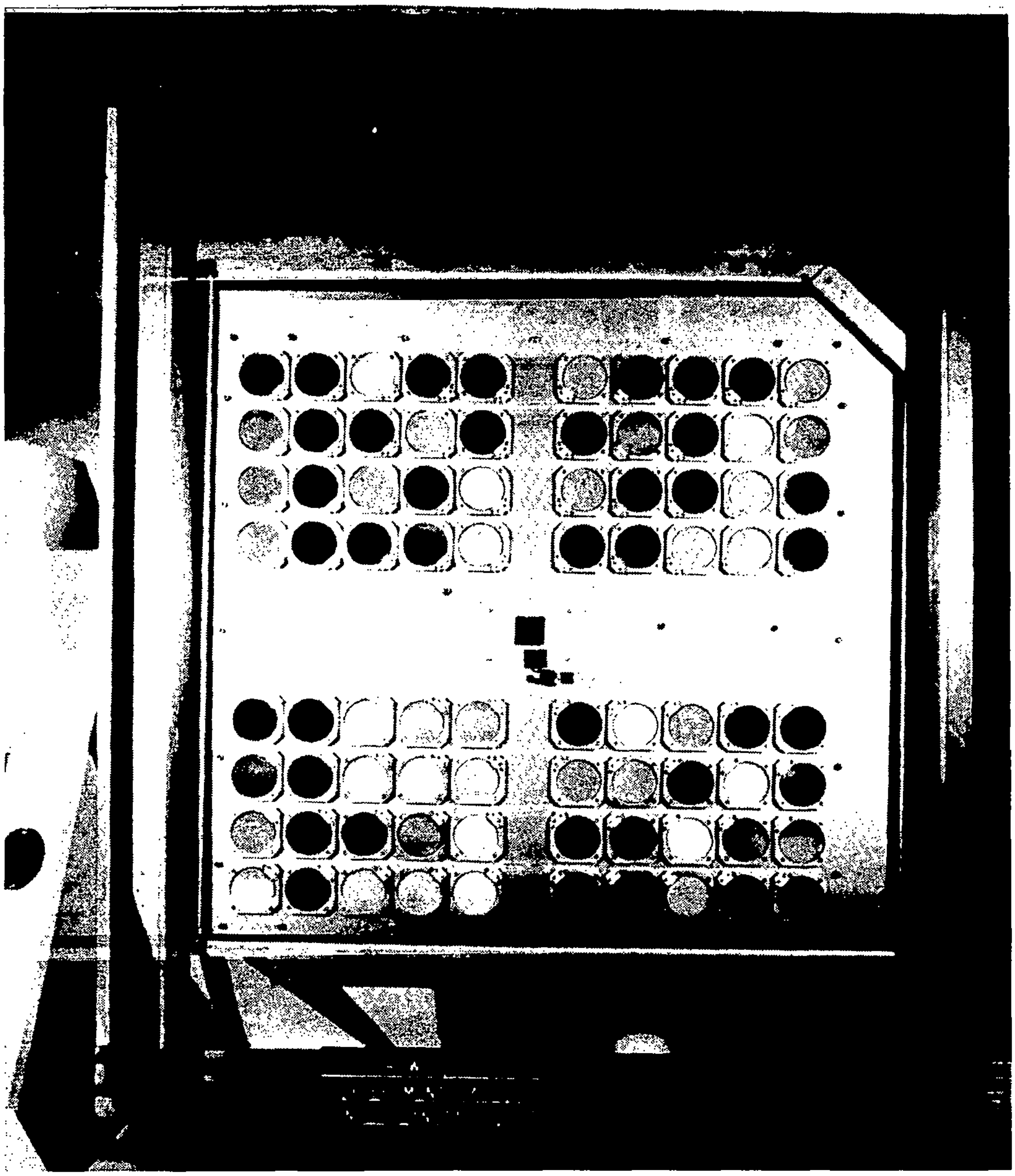
Pre-Flight - 108-KSC-384C-8/6
On-Orbit - S32-76-50
Pre-Deintegration - KSC-390C-833.04
Post Deintegration - KSC-390C-2068.08
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - G10C01, G10C04, G10C06, G10C08, G10C10, and G10C12

ACCOMPANYING FIGURES:

Figure G10-1. This post-deintegration view shows the front of the entire G10 experiment tray.



LDEF LOCATION: G12

EXPERIMENT IDENTIFICATION: A0056

EXPERIMENT TITLE: EXPOSURE TO SPACE RADIATION OF HIGH-PERFORMANCE INFRARED MULTI-LAYER FILTERS AND MATERIALS TECHNOLOGY EXPERIMENTS

PRINCIPAL INVESTIGATOR: J. SEELY
UNIVERSITY OF ALABAMA, HUNTSVILLE
HUNTSVILLE, AL 35899

A0147
PASSIVE EXPOSURE OF EARTH RADIATION BUDGET EXPERIMENT COMPONENTS
J. HICKEY
THE EPPLEY LABORATORY
12 SHEFFIELD AVENUE
NEWPORT, RHODE ISLAND 02840

A0172
EFFECT OF SOLAR RADIATION ON GLASSES
R. NICHOLS
EH34, NASA MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

M0002-1
TRAPPED-PROTON ENERGY SPECTRUM DETERMINATION
R. FREDRICKSON
UNITED STATES AIR FORCE GEOPHYSICS LABORATORY/PHP
HANSCOM AIR FORCE BASE, MASSACHUSETTS 01731-5000

SUMMARY OF OBSERVATIONS

Earth-end Bay G12 contained a passive 3"-deep (7.6 cm), integrated experiment tray which housed four separate experiments, each occupying 25 percent of the tray. The objectives of the A0056 experiment was to investigate the effects of near-Earth space on multi-layer filters, semiconductors, and various spacecraft surface finishes. The experimental package consisted of 20 coated and uncoated glass- and semiconductor

infrared filter substrates mounted in a 6061-T6 aluminum panel. There were also several carbon-fiber reinforced plastic structural material samples with various thermal coatings as part of the experiment. This experiment had a second set of samples occupying a third of the Bay B08 experiment tray.

The objectives of the A0147 experimental package was to expose Earth-flux channel components to the space environment in order to calibrate the information gathered from similar devices which were on the Earth Radiation Budget experiments which flew on Nimbus 6 and 7. The three Earth-flux channel components included small optical surfaces which were mounted in a 6061-T6 aluminum plate which was painted white with Chemglaze Z302. The Solar-channel components of the A0147 experiment occupied one sixth of the B08 experiment tray.

Experiment A0172 consisted of fifty two 1.25" (3.2 cm) diameter samples of coated and uncoated glasses mounted in a 0.375" (9.5 mm) thick, 6061-T6 aluminum plate which was painted white with Chemglaze II A276. The purpose of this experiment was to investigate the effects of solar radiation and the near-Earth space environment on the optical, mechanical, and chemical properties of glasses. An additional set of 72 samples were mounted in the D02 experiment tray.

The M0002-1 experiment was designed to measure the flux and energy spectrum of protons with energies of 1 to 10 MeV. The experimental package consisted of six stacks of plastic, passive proton (CR-39) detectors which were mounted in 6061-T6 aluminum housings which, in turn, were attached to an aluminum baseplate. In addition, this package included an aluminum tube which was filled with metal microspheres mounted to the same baseplate. All of the mounting hardware was painted white. The proton detectors faced outward in several directions (none of which were parallel with the experiment-tray surface) in order to provide directional information on protons trapped in the Earth's magnetic field. Similar detectors were mounted to the experiment trays in Bays B03 and D09.

There were a total of five features identified on all G12 experimental- and experiment-tray surfaces, all of which were <0.5 mm in diameter. Four of these features were located on the experiment-tray flanges and one was located on the A0056 experimental surfaces. This latter feature was a impact, with associated spall and fracture zones, in one of the coated glass samples of the A0056 experiment.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm		4		4
>0.5 mm			1	1
TOTALS		4	1	5

The largest impact feature found on this tray was the ~0.5 mm features discuss above.

M&D SIG INSPECTIONS

PRE-DEINTEGRATION:

One feature <0.5 mm in diameter was identified on the inner part of the top experiment-tray flange during the visual inspection conducted on February 21, 1990 of Bay G12 while the tray was still mounted to LDEF. However, as a result of the features size, the experiment-tray cover gasket was not modified.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick, chromic-anodized 6061-T6 experiment-tray flanges.

DOCUMENTATION:

Tray G12 was inspected in the vertical position utilizing M&D SIG System #1 on March 11, 1990; feature coordinates were determined using Coordinate Registration System #3. The experiment-tray clamps, bolts, and shims were inspected on March 15, 1990 with M&D SIG System #3; no images were taken.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.G12	RE000001.G12	614	765		0.5	glass	*1,b,m*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Penetration of sample.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-317/8
On-Orbit - S32-76-54
Pre-Deintegration - KSC-390C-1034.02
Post Deintegration - KSC-390C-1997.01
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - G12C06, G12C07, G12C09, G12C10, G12C011, and G12C012

LDEF LOCATION: H01
TRAY IDENTIFICATION: S1001
EXPERIMENT TITLE: LOW-TEMPERATURE HEAT PIPE EXPERIMENT PACKAGE (HEPP) FOR LDEF
PRINCIPAL INVESTIGATOR: R. McINTOSH, Jr.
NASA GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

SUMMARY OF OBSERVATIONS

Bay H01 was occupied by a 12"-deep (30.5 cm), active experiment-tray which was one of two experiment-trays comprising the S1001 experiment; the other tray was located in Bay F12 and was also active. Tray H01 contained the power source for the Heat Pipe Experiment Package (HEPP), and contained an 8000 watt-hour nickel-cadmium (NiCd) battery and four silicon solar-cell arrays which were coated with a silicon-monixide anti-reflection coating. The solar arrays were attached to an aluminum mounting plate which had been painted green with a silicate paint; a set of thermal-control samples were also attached to the rim of the experiment tray. Bay F12 contained the hardware and the experiment power and data system (EPDS) for data collection and storage for this experiment. The HEPP was designed to evaluate the "0-Gravity" performance of low-temperature (<190° K) heat pipes on the Long Duration Exposure Facility.

Impact features in the solar-cell cover glasses usually exhibited a large concodial fracture zone in association with a small to non-existent central pit. In addition, large radiating cracks originating from the outer portion of the central fracture zone were commonly assocaited with features observed in this material. Several features in the green aluminum mounting plate possessed large spall zones in which the first layer of paint had been removed. On average, these circular spall zones were twice the diameter of the centrally located crater. Two features were observed which appeared to have some sort of residue in the bottom of the shallow craters. All features in aluminum surfaces were typical of craters produced in similar materials under controlled laboratory hypervelocity impact tests.

On tray H01, the M&D SIG survey identified a total of 179 impact features on all surfaces associated with the experiment tray. These surfaces included the experiment-tray flanges (0.0625" [1.6 mm] thick, chromic-anodized 6061-T6 aluminum), the experiment-tray clamps (0.18" [4.5 mm] thick, chromic-anodized 6061-T6 aluminum), the stainless steel clamp bolts, the green aluminum mounting plate, and the four solar arrays. Of the 179 features identified, 153 were <0.5 mm in diameter and were not imaged. Seventeen of these were located on the green mounting plate, 74 on the solar arrays, 32 on the experiment-tray flanges, and 30 on clamps (C01 - C12). All of the remaining 26 features were photodocumented, three of which resided on the experiment-tray flanges, five on clamps C05, C08, and C10, four on the green aluminum mounting plate, and 14 on the four solar arrays.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	30	32	91	153
>0.5 mm	5	3	18	26
TOTALS	35	35	109	179

The largest impact features identified on this tray were (1) an ~0.8 mm in diameter feature on the experiment-tray flange, (2) an ~2.1 mm in diameter feature on clamp C08, and (3) an ~3.0 mm diameter fracture zone located on one of the solar arrays. Image LE000003.H01 was taken of an apparent multi-cratering event on the green aluminum mounting plate.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection of Bay H01 was conducted on February 21, 1990, while the experiment-tray was mounted on the spacecraft, and identified two features that might be damaged by the installation of the experiment-tray cover, and one additional feature that could be damaged or destroyed by the experiment-tray rotator clamping mechanism. In an effort to protect the more interesting feature within the experiment-tray cover area, the cover gasket was cut in two locations to prevent it from coming into contact with these features and to provide a stand-off distance between the experiment-tray cover and flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick, chromic-anodized 6061-T6 experiment-tray flanges.

DOCUMENTATION:

On March 27, 1990 the green aluminum mounting plate and experiment-tray flanges were inspected and photodocumented in the vertical position utilizing M&D SIG System #2 and Coordinate Registration System #2. All features which were imaged during this initial inspection were assigned Component Number "E00". The second detailed inspection was conducted on March 28, 1990, and examined the uncovered solar arrays; this inspection was performed with the tray in the vertical position using M&D SIG System #1. Features identified on the solar-cell surfaces were assigned Component Number "E01"; coordinates for these features were determined using a metric tape measure. The detailed inspection of the experiment-tray clamps, bolts, and shims was also performed on March 28, 1990 on M&D SIG System #3 using a metric scale to determine feature coordinates.

At least three of the features in the solar arrays did not possess a central crater or pit, and, as a result, diameters were not obtained on these features. However, the extent of the associated fracture zone was measured for one of these features.

Bolt-hole Registration - Not Determined

Impact Features Imaged on Experimental-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC050001.H01	RC050001.H01	49	49		0.7 x 0.5	Al	*1,j*
LC050002.H01	RC050002.H01	21	127		0.9	Al	*2*
LC080001.H01	RC080001.H01	38	5		0.6	Al	
LC080002.H01	RC080002.H01	22	32		2.0	Al	
LC100001.H01	RC100001.H01	46	120		0.6	Al	*3*

Impact Features Imaged on Experimental-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.H01	RE000001.H01	800	204		0.5	Al	
LE000006.H01	RE000006.H01	790	-108		0.7	Al	
LE000007.H01	RE000007.H01	155	-105		0.3	Al	*4*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.H01	RE000002.H01	764	358		0.6	solar cell	*5,k*
LE000003.H01	RE000003.H01	390	336		0.3	solar cell	*6,j*
LE000004.H01	RE000004.H01	40	250		0.4	solar cell	*k*
LE000005.H01	RE000005.H01	295	-75		0.5 x 0.4	solar cell	
LE010001.H01	RE010001.H01	200	490		0.2	solar cell	*7,8,9*
LE010002.H01	RE010002.H01	95	410		0.2	solar cell	*7,8,10*
LE010003.H01	RE010003.H01	561	580		ND	solar cell	*7,8,11,13*
LE010004.H01	RE010004.H01	511	405		0.3	solar cell	*7,8,11*
LE010005.H01	RE010005.H01	518	400		0.3	solar cell	*7,8,12*
LE010006.H01	RE010006.H01	676	435		ND	solar cell	*13*
LE010007.H01	RE010007.H01	565	237		0.3	solar cell	*7,8,14*
LE010008.H01	RE010008.H01	552	78		0.2	solar cell	*7,8,15*
LE010009.H01	RE010009.H01	709	45		0.3	solar cell	*7,8,16*
LE010010.H01	RE010010.H01	220	0		0.3	solar cell	*7,8,16*
LE010011.H01	RE010011.H01	260	67		0.4	solar cell	*7,8,17*
LE010012.H01	RE010012.H01	282	140		ND	solar cell	*7,8,13*
LE010013.H01	RE010013.H01	343	135		ND	solar cell	*7,8,13*
LE010014.H01	RE010014.H01	348	139		ND	solar cell	*7,8,13*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Possible multiple-cratering event on corner of clamp.
2 - Feature on edge of clamp.
3 - Wrong coordinates (X = 0, Y = 0) eneter in image file.
4 - Image taken at ~10° from normal of crater.
5 - Outer fracture zone diameter ≈ 0.6 mm.
6 - Outer fracture zone diameter ≈ 0.7 mm.
7 - Concodial fracture in the cover glass.
8 - Radial cracks.
9 - Outer fracture zone diameter ≈ 1.8 mm.
10 - Outer fracture zone diameter ≈ 1.4 mm.
11 - Outer fracture zone diameter ≈ 2.0 mm.
12 - Outer fracture zone diameter ≈ 2.4 mm.
13 - No central pit, no diameter measured.
14 - Outer fracture zone diameter ≈ 3.2 mm.
15 - Outer fracture zone diameter ≈ 1.8 mm.
16 - Outer fracture zone diameter ≈ 2.3 mm.
17 - Outer fracture zone diameter ≈ 1.2 mm.

OTHER PHOTODOCUMENTATION:

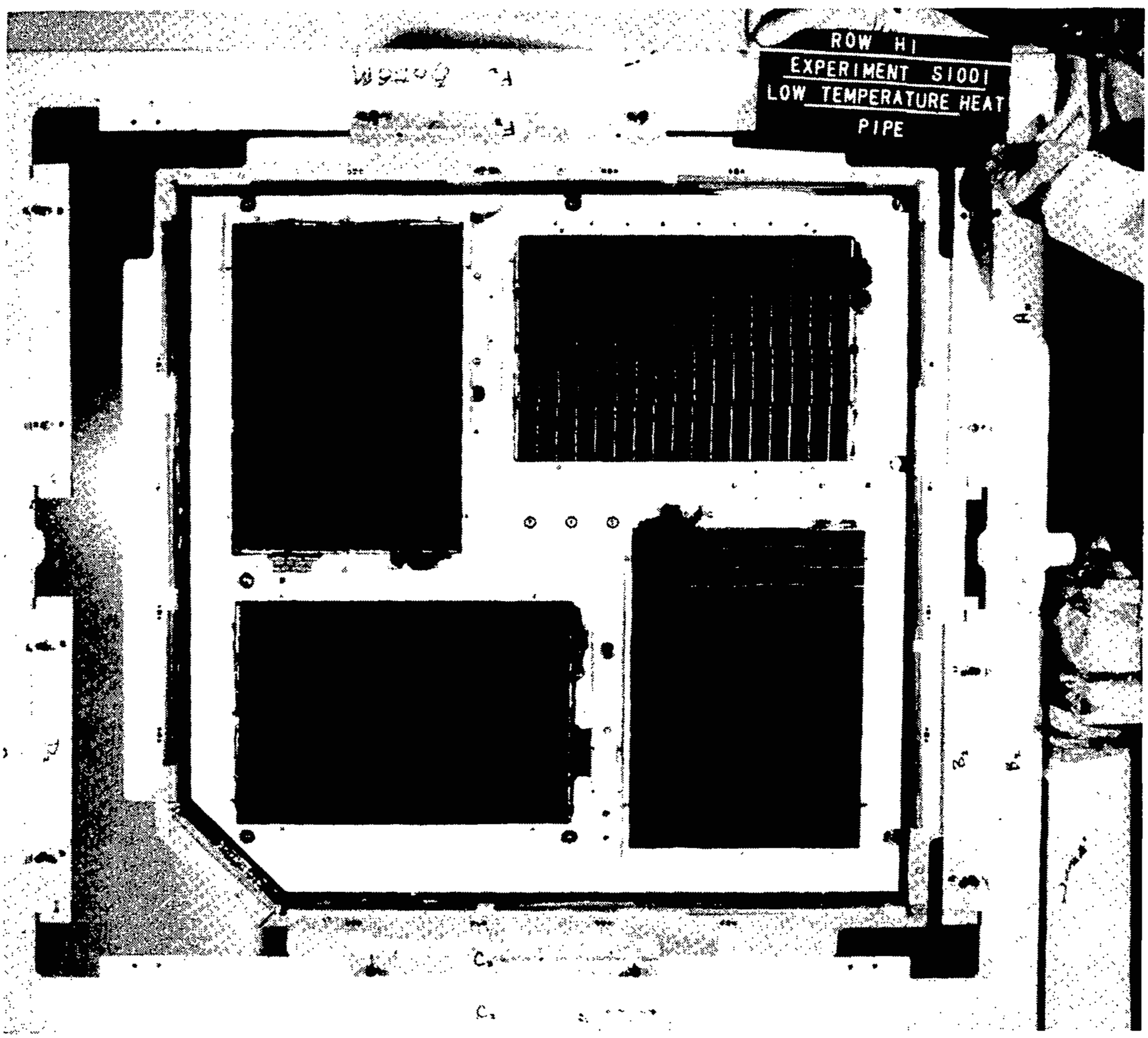
Pre-Flight
On-Orbit - S32-85-06
Pre-deintegration - KSC-390C-832.10, KSC-390C-832.11, KSC-390C-833.02, KSC-390C-1030.04
Post Deintegration - KSC-390C-2367.04
M&D SIG Photos - None

ARCHIVED MATERIALS

Clamps - H01C01, H01C05, H01C08, H01C09, H01C10, and H01C12
Clamp Bolts - H01S03C
Clamp Shims - H01H02

ACCOMPANYING FIGURES:

Figure H01-1: This post-deintegration view shows the front of the entire H01 experiment tray.



LDEF LOCATION: H03
EXPERIMENT IDENTIFICATION: M0001
EXPERIMENT TITLE: HEAVY IONS IN SPACE
PRINCIPAL INVESTIGATOR: J. ADAMS
NAVAL RESEARCH LABORATORY
WASHINGTON, DISTRICT OF COLUMBIA

SUMMARY OF OBSERVATIONS

Bay H03 contained a 12"-deep (30.5 cm) experiment tray which accommodated one of two M0001 passive experiments, the other of which was located in Bay H12. The objective of this experiment was to investigate three components of heavy nuclei in space: (1) a recently observed anomalous component of low-energy nuclei of N, O, and Ne, (2) the heavy nuclei in the Van Allen radiation belts, and (3) the ultra-heavy (UH) nuclei (atomic number [Z]>30) of the galactic radiation. The experimental package consisted of eight detector modules (four each in Bays H03 and H12); each module or stack possessed an active area of 12" x 14" (30.5 x 35.6 cm). Individual stacks consisted of two parts, one for low-energy ions and one for cosmic rays. The larger cosmic-ray detectors resided in sealed containers, below the low-energy ion detectors, and consisted of sheets of track-detecting (primarily CR-39) plastic. The low-energy ion detectors consisted of lexan sheets which were secured to the top of the cosmic-ray detectors by aluminum frames, termed "Z-frames". Each stack was shielded from the space environment by a multi-layer insulation blanket composed of alternating layers of 0.25 mil (~25 μm) thick sheets of Dupont Type-A Mylar (aluminized on both sides) and Dupont Dacron netting (70-886-10). The top layer (space-facing) of these blankets, a Dupont Kapton aluminized H-film, was painted white with Chemglaze II. This paint consisted of inorganic pigment grains held within an organic-based binder. The blankets were attached to the Z-frames with a space-qualified tape.

A notable feature of the multi-layer thermal blankets was that they had curled back on orbit, exposing themselves to oxygen erosion. Blanket surfaces which had not curled back were a coffee-brown color, while surfaces which had curled back and were subjected to direct oxygen erosion were a mottled brown and white. Impacts into the brown blankets exhibited spalled regions which were white, suggesting that the impact shock had removed surficial brown material. There were many apparent low-angle impacts into these blankets, as indicated by elongated white spall features. As a result of the blankets curling back, impacts were found on both the top- and backsides of many blankets. Several notable impact features were present on the multi-layer thermal blankets which suggested entry from the rear, undoubtedly occurring after the blanket had curled back. Impacts from the rear produced bulges, and occasional cracks in the blanket layers. Most impacts into the lexan sheets, which became exposed after the thermal blankets had peeled back, were accompanied by radial cracks within the top lexan layer. Several of the impactors penetrated more than one layer of lexan, one up to eight layers. The M0001 thermal blankets should have served as good meteoroid and debris collection cells.

The M&D SIG survey identified a total of 154 impact features on the H03 experiment tray, the multi-layer blankets removed prior to experiment-tray deintegration, and the associated clamps, bolts, and shims. Unlike later documentation activities for tray H03 (and H12), all impact features optically discernable on the multi-layer blankets were photodocumented. The photodocumentation of the thermal blankets for H03 and H12 was conducted before the experiment tray was removed from LDEF, as several of the blankets had to be removed to facilitate LDEF rotation and deintegration operations. Features which were photodocumented on the three removed thermal blankets were assigned different "Component Numbers" (E01, E02, and E04) than those which were photodocumented on the experiment tray (E00; Figure H03-1). Of the 154 features identified, 108 were <0.3 mm in diameter (70 of which were not separated as to their location [*e.g.*, experiment-tray flanges or experimental surface]). On the experimental surfaces, 38 features were <0.3 mm in diameter (29 of which were found on the blankets which were removed before the experiment tray, and nine which were found on the remaining integrated tray), 15 were between 0.3 mm and 1.0 mm diameter in the

blankets, two were between 0.5 mm and 1.0 mm in diameter in the aluminum Z-frames, and one was >5.0 mm in diameter in the aluminum Z-frames. In addition, three features of unknown dimensions were found on the thermal blankets and a Z-frame (two and one, respectively). On the experiment-tray flanges, one impact feature was <0.5 mm in diameter and was not photodocumented , and two were between 0.5 mm and 1.0 mm in diameter. Of the 24 impacts into the experiment-tray clamps, 21 were <0.5 mm in diameter and were not photodocumented, and three were between 0.5 mm and 1.0 mm in diameter.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm				108*
>0.3 mm			15	15
<0.5 mm	21			23*
>0.5 mm	3	2	3	8
TOTALS	24			154

* The locations of the "Too Smalls" were not documented.

The largest impact features identified on this tray were (1) an ~5.3 mm diameter crater on an aluminum Z-frame on, (2) an ~0.5 mm diameter crater on the experiment-tray flanges, and (3) an ~0.5 mm diameter crater on an experiment-tray clamp. The ~5.3 mm diameter crater was the largest impact feature found on the entire LDEF spacecraft by the M&D SIG. This particular impact occurred in the side of the aluminum Z-frame of Module "A" (M&D SIG Component Number E01), and deposited a large amount of ejecta onto the facing side of the adjacent aluminum Z-frame of Module "D" (M&D SIG Component Number E04). In addition, the impact produced a bulge (~3 mm) on the backside of the Module "A" Z-frame (to the limit allowed by the sealed CR-39 container directly behind frame).

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The standard M&D SIG pre-deintegration inspection was conducted on February 20, 1990, at which time the experiment-tray cover had already been installed. However, four features were identified on the various clamps, only one of which was in an area requiring the use of an open-end wrench during the removal of bolt C02C to prevent damage to this feature. As had been noted during LDEF retrieval operations, the thermal blankets had become partially detached from the Z-frames and were peeling back. These loose blankets had to be removed from the experiment tray before the experiment-tray cover could be installed. Accordingly, on February 6, 1990, thermal blankets "A", "B", and "D" were removed from the experiment tray by the experiment's Principal Investigator (PI). In addition, the PI used Mylar tape to securely re-attached the two sides of blanket "C", which had split diagonally across the middle and peeled back; this blanket was left attached to the experiment tray. Each removed blanket was stapled together along one edge (taking care to not disturb impact features), to permit later registration of particulate penetrations through multiple-blanket layers. In places where the thermal blanket had peeled

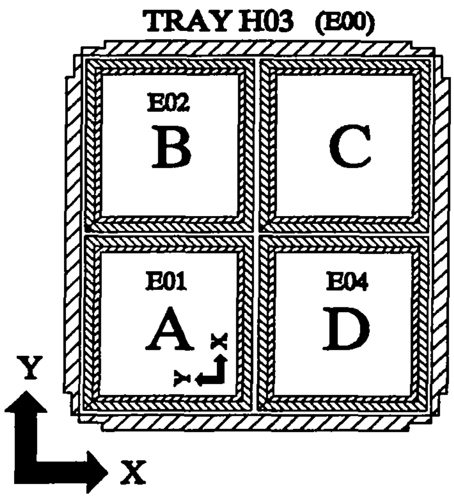


Figure H03-1. Diagram illustrating the orientation of the experiment tray and multi-layer thermal blankets during M&D SIG photodocumentation.

back on orbit, impact features were apparent in the lexan detector stacks. Some impact features were accompanied by cracks (*e.g.*, Detector "D"). No impacts were noted in the portions of the lexan detectors which were still shielded by the multi-layer blankets.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (30.5 mm) thick, chromic-anodized 6061-T6 experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of the H03 experiment tray was conducted on March 15, 1990 in the vertical position utilizing M&D SIG System #2. Blankets "A", "B", and "D", which had been previously removed from the tray, were documented utilizing M&D SIG Systems #1, #2, and #3 on February 7 through 9, 1990. The bolts, clamps, and shims associated with this experiment-tray were scanned with M&D SIG System #3 on March 15, 1990. Coordinates for all photodocumented features were measured with a metric tape measure or scale. Note that blanket "A" (component E01) was documented in an orientation rotated 90° clockwise from that of the remaining blankets and the experiment tray (Figure H03-1).

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC020001.H03	RC020001.H03	119	32		0.5	Al	
LC040001.H03	RC040001.H03	10	103		1.0	Al	
LC080001.H03	RC080001.H03	33	19		0.6	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.H03	RE000001.H03	-15	673		0.5	Al	
LE000011.H03	RE000011.H03	51	-15		0.5	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.H03	RE000002.H03	544	732		0.4	MTB	*d*
LE000003.H03	RE000003.H03	430	672		0.3	MTB	
LE000004.H03	RE000004.H03	362	622		ND	Al (Z-frame)	*1*
LE000005.H03	RE000005.H03	121	438		0.1	Al (Z-frame)	*2,b*
LE000006.H03	RE000006.H03	81	633		0.1 x 0.2	Al	*3,b*
LE000007.H03	RE000007.H03	361	253		5.3	Al (Z-frame)	*4*
LE000008.H03	RE000008.H03	300	393		0.5	Al	
LE000009.H03	RE000009.H03	566	272		0.2	Al (Foil)	
LE000010.H03	RE000010.H03	648	533.		0.7	MTB	
LE000012.H03	RE000012.H03	329	48		0.2 x 0.3	Lexan	
LE000013.H03	RE000013.H03	485	114		0.2 x 0.3	Lexan	*m*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000014.H03	RE000014.H03	524	103		0.3 x 0.4	Lexan	*m*
LE000015.H03	RE000015.H03	445	34		0.3	Lexan	*m*
LE010001.H03	RE010001.H03	35	80		0.7	MTB	*z*
LE010002.H03	RE010002.H03	258	111		0.6 x 0.8	MTB	*z*
LE010003.H03	RE010003.H03	180	172		0.3	MTB	*m,z*
LE010004.H03	RE010004.H03	212	205		0.2	MTB	*z*
LE010005.H03	RE010005.H03	183	338		0.2 x 0.3	MTB	*z*
LE010006.H03	RE010006.H03	28	291		0.1	MTB	*z*
LE010007.H03	RE010007.H03	4	243		0.1	MTB	*z*
LE010008.H03	RE010008.H03	107	350		0.1	MTB	*z*
LE010009.H03	RE010009.H03	155	146		0.1	MTB	*z*
LE020001.H03	RE020001.H03	52	20		0.2	MTB	*m*
LE020002.H03	RE020002.H03	57	29		0.1 x 0.2	MTB	*m*
LE020003.H03	RE020003.H03	154	8		0.3	MTB	*5,a,b*
LE020004.H03	RE020004.H03	241	15		0.1 x 0.2	MTB	
LE020005.H03	RE020005.H03	255	15		0.1 x 0.2	MTB	
LE020006.H03	RE020006.H03	285	75		0.1	MTB	*m*
LE020007.H03	RE020007.H03	299	153		0.2	MTB	*m*
LE020008.H03	RE020008.H03	253	165		0.2	MTB	
LE020009.H03	RE020009.H03	264	273		ND	MTB	*m*
LE020010.H03	RE020010.H03	274	295		0.1	MTB	
LE020011.H03	RE020011.H03	320	350		0.2	MTB	
LE020012.H03	RE020012.H03	238	327		0.2 x 0.3	MTB	
LE020013.H03	RE020013.H03	49	230		0.1	MTB	
LE020014.H03	RE020014.H03	49	234		0.1	MTB	
LE020015.H03	RE020015.H03	213	135		0.1	MTB	*m*
LE020016.H03	RE020016.H03	10	200		0.2	MTB	
LE020017.H03	RE020017.H03	10	130		ND	MTB	*7*
LE020018.H03	RE020018.H03	21	110		0.3	MTB	
LE020019.H03	RE020019.H03	20	153		0.1 x 0.2	MTB	
LE040001.H03	RE040001.H03	118	90		0.2	MTB	*8,k*
LE040002.H03	RE040002.H03	240	117		0.5	MTB	
LE040003.H03	RE040003.H03	230	150		0.3 x 0.4	MTB	*9,m*
LE040004.H03	RE040004.H03	264	170		0.3	Al (Foil)	*m*
AE040004.H03	BE040004.H03	264	170		0.3	Al (Foil)	*m*
LE040005.H03	RE040005.H03	37	147		0.6	MTB	*k*
LE040006.H03	RE040006.H03	31	144		0.5	MTB	
LE040007.H03	RE040007.H03	27	170		0.3	MTB	
LE040008.H03	RE040008.H03	30	185		0.3	MTB	*d,k*
AE040008.H03	BE040008.H03	30	185		0.3	MTB	*d,k*
CE040008.H03	DE040008.H03	30	185		0.3	MTB	*d,k*
LE040009.H03	RE040009.H03	13	334		0.2	MTB	
LE040010.H03	RE040010.H03	46	255		0.1	MTB	
LE040011.H03	RE040011.H03	205	260		0.1	MTB	*m*
LE040012.H03	RE040012.H03	150	335		0.1	MTB	
LE040013.H03	RE040013.H03	275	245		0.2	MTB	*m,x*
AE040013.H03	BE040013.H03	275	245		0.2	MTB	*m,x*
LF010001.H03	RF010001.H03	363	250		5.3	MTB	*10*
AF010001.H03	BF010001.H03	363	250		ND	MTB	*10,x*
CF010001.H03	DF010001.H03	363	250		ND	MTB	*10,x*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

MTB - Multi-layer thermal blanket
ND - Not Determined

1 - Apparent low-angle impact into side of Z-frame, no diameter taken at KSC.
2 - ~4.3 mm outer crater rim; spall?
3 - ~6.0 mm outer crater rim; spall?
4 - An impact onto right side of Z-frame of Module "A"; significant ejecta onto adjacent Z-frame of Module "D". This is the largest impact feature on LDEF.
5 - Spall zone and halo present.
6 - Very irregular-shaped penetration, no diameter estimated.
7 - Two penetrations from the rear of the multi-layer blanket are shown in this image, no diameters estimated.
8 - Diameter given is for the penetration hole, the crater measures ~0.6 mm in diameter.
9 - An impact from the rear of the blanket.
10 - Same feature as LE000007, however these images were taken from normal incidence after removal of the Z-frames from the experiment tray; last two images taken of rear bulge in Z-frame.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-348C-318/1
On-Orbit - S32-75-43, S32-85-06
Pre-Deintegration - KSC-390C-828.01 through KSC-390C-828.04, KSC-390C-828.09 through KSC-390C-828.11, KSC-390C-829.04, KSC-390C-829.05, KSC-390C-829.08, KSC-390C-829.10 through KSC-390C-829.12, KSC-390C-833.02, KSC-390C-1011.05, KSC-390C-1011.06, KSC-390C-1011.09 through KSC-390C-1011.12, KSC-390C-1012.09 through KSC-390C-1012.12, KSC-390C-1013.01 through KSC-390C-1013.05, KSC-390C-1030.04
Post Deintegration - KSC-390C-1012.06 through KSC-390C-1012.08, KSC-390C-2031.08, KSC-390C-2033.08 through KSC-390C-2033.12
M&D SIG Photos - S90-43502 through S90-43504, S90-43375, S90-43388 through S90-43390

ARCHIVED MATERIALS:

Clamps - H03C01, H03C02, H03C04, H03C06, H03C08, and H03C09
Other - H03E00A - Top Lexan Detector Sheet (Detector "B")
H03E00B - Top Lexan Detector Sheet (Detector "D")
H03F01 - Aluminum Z-frame (Module "A"; crater)
H03F02 - Aluminum Z-frame (Module"D"; ejecta)
LD-98 through LD-101 - Feature H03E00,13 (5 lexan layers)
LD-95 through LD-97 - Feature H03E00,14 (4 lexan layers)
LD-88 through LD-94 - Feature H03E00,15 (8 lexan layers)

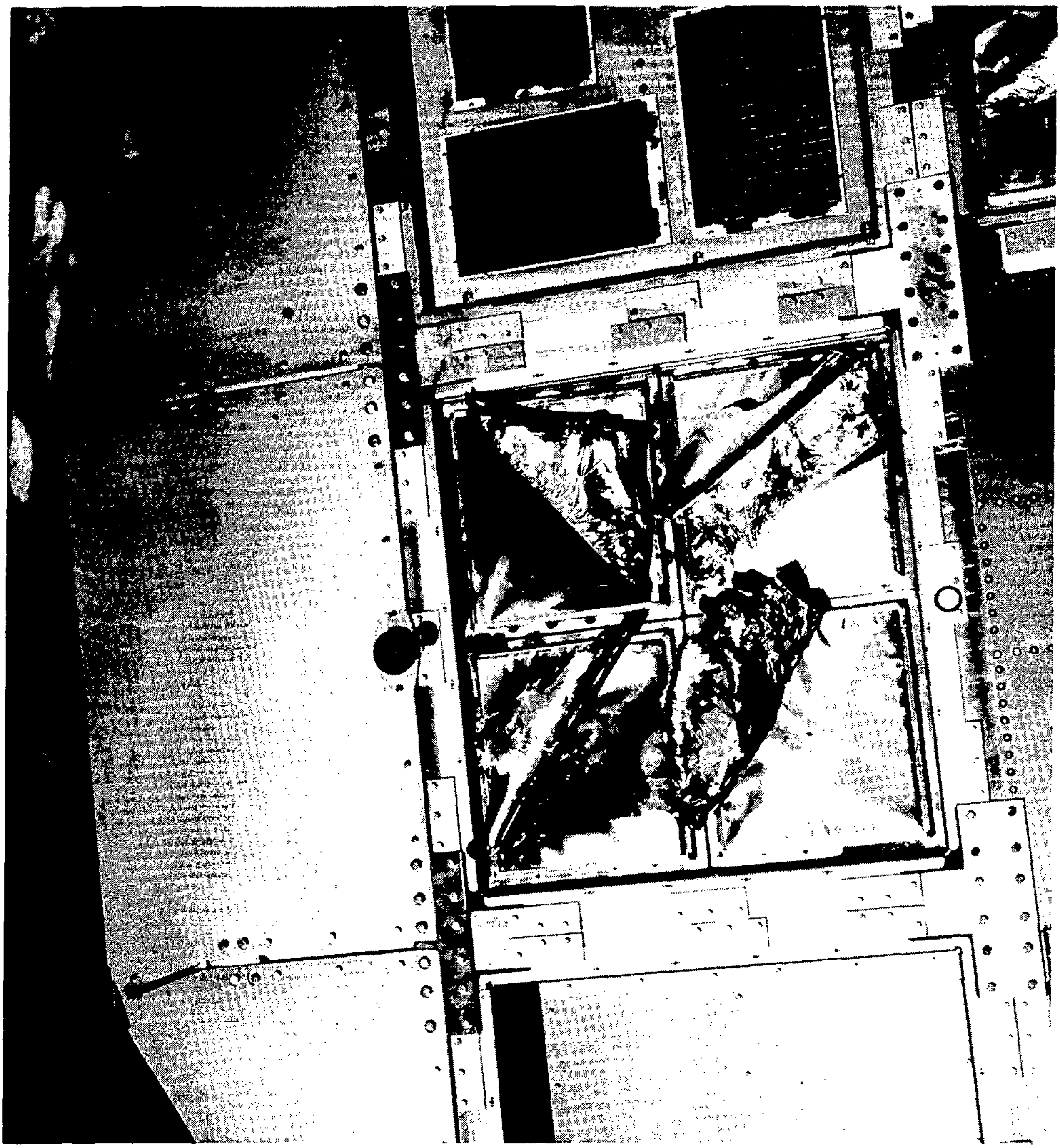
NOTE - The cores listed above indicate 5, 4, and 8 layers, respectively, for these features, but the JSC database only lists 4, 3, and 7 layers, respectively; there is no listing within the JSC database for cores from layer 1 for these three features.

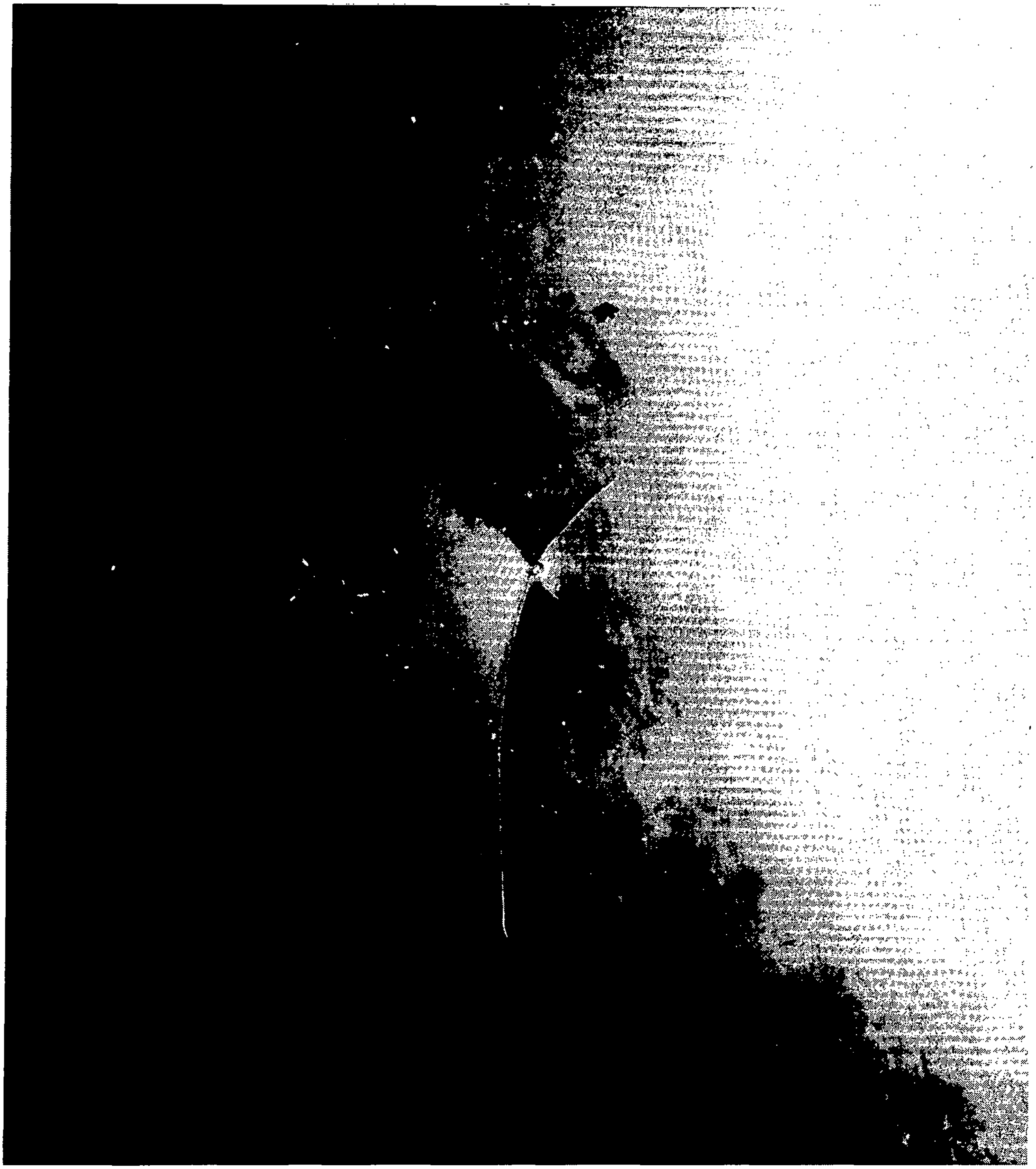
ACCOMPANYING FIGURES:

Figure H03-2. This on-orbit Space Shuttle view shows the front of the entire H03 experiment tray. Multi-layer thermal blankets have become partially detached and are peeling back, exposing the underlying lexan detector stacks to the particulate environment.

Figure H03-3. This is a side view of the largest impact feature on LDEF (LE000007.H03). The impactor hit the right side of the aluminum Z-frame on the left (Module "A"), and ejecta was deposited across the intervening space to the adjacent Z-frame on the right (Module "D"). This view measures approximately 10 cm across.

Figure H03-4. This view shows an impact penetration located in lexan detector stack "D", in a place where the thermal blanket had peeled back and exposed the lexan to the particulate environment. The impact penetrates eight layers of lexan, but the large crack only effected the top-most layer. This view measures approximately 8 cm across.





LDEF LOCATION: H05
EXPERIMENT IDENTIFICATION: S0001
EXPERIMENT TITLE: SPACE DEBRIS IMPACT EXPERIMENT
PRINCIPAL INVESTIGATOR: D. HUMES
493 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665-5225

SUMMARY OF OBSERVATIONS

Bay H05 held one of nineteen 3"-deep (7.6 cm), passive peripheral experiment trays that were part of the S0001 Meteoroid and Debris Experiment. In addition, this experiment exposed three end-corner trays (two on the Earth end and one on the space end), as well as three other partial (2/3) trays around the periphery of the spacecraft. Each peripheral tray consisted of two equal-sized, 0.125" (3.2 mm) thick, 6061-T6 aluminum sheets, while the three end-trays exposed a single sheet of the same material. An S0001 experiment tray was located on all rows except Row 9, the leading-edge direction. From the M&D SIG point of view, the S0001 experiment is extremely important because it exposed a large (~25 m^2), uniform meteoroid and debris detection surface in all but the leading-edge direction.

The M&D SIG survey identified 112 features on the H05 experiment-tray hardware and experimental surfaces. Eighty four of these were <0.5 mm in diameter; 51 of which were located on various experiment-tray hardware (43 on the experiment-tray flanges and walls, seven on various clamps, and one on a stainless steel bolt), and 33 were located on the 0.125" (3.2 mm) thick, 6061-T6 aluminum detector surface. Three features (one each on clamps C02 and C06, and one on bolt C06C) measured <0.5 mm in diameter, but were imaged. Eight features (>0.5 mm in diameter) were photodocumented from the experiment-tray hardware (five from various clamps, two on the experiment-tray flanges, and one on bolt C02B), while 21 features >0.5 mm in diameter were photodocumented from the experimental surface. Several features on the experimental surface exhibited significant debris deposits in association with the impact. One of these measured ~0.7 mm in diameter (LE000003.H05), and was an impact into a stainless steel allen-head bolt, the associated debris deposit (on the washer and adjacent aluminum detector surface) was imaged as well (AE000003.H05). Two additional features had associated debris deposits (LE000015.H05 [~0.6 mm in diameter] and an oblique feature LE000005.H05 [~0.5 x 0.9 mm]). All features examined on this tray were typical of craters produced in similar material under controlled laboratory hypervelocity impact conditions.

The largest features identified on the H05 experiment tray were (1) two ~0.9 mm diameter features on the aluminum detector surface and (2) an ~1.2 mm diameter feature on an experiment-tray flange.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	8	43	33	84
>0.5 mm	5	2	21	28
TOTALS	13	45	54	112

M&D SIG INSPECTIONS

PRE-DEINTEGRATION:

An initial inspection of the Bay H05 experiment tray was performed on February 22, 1990 in order to document features which might be altered during tray deintegration activities. During this inspection 12 features were identified (six on the experiment-tray flanges and six on the various clamps). None of the

features on the clamps were in locations where they could be damaged by tools used to removed the bolts. Since all S0001 experiments were examined on a workbench, there was no concern of damage (from the experiment-tray rotator clamping mechanism) to features residing on the flanges.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.0625" (1.6 mm) thick, chromic-anodized 6061-T6 experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of experiment tray H05 was conducted on March 2, 1990 in the horizontal position utilizing M&D SIG System #3. The bolts, clamps, and shims associated with this tray were scanned and imaged on March 5, 1990 with M&D SIG System #3. The coordinates for all features associated with this tray were measured with a metric tape measure or scale. The (0,0) reference point for this tray was placed at the intersection of the left experiment-tray flange, and the top of the 45° corner flange (see Section 2.C.6.a, Figure 25).

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC020001.H05	RC020001.H05	35	13		0.4	Al	
LC030001.H05	RC030001.H05	9	1		0.4	Al	
LC060001.H05	RC060001.H05	46	4		0.5	Al	
LC110001.H05	RC110001.H05	30	93		0.5	Al	
LC120001.H05	RC120001.H05	29	104		0.5	Al	
LC120002.H05	RC120002.H05	43	44		0.5	Al	
LS020001.H05	RS020001.H05	3	4		0.5	stainless steel	*4*
LS060001.H05	RS060001.H05	-1	2		0.2	stainless steel	*5*

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.H05	RE000001.H05	233	-60		0.7	Al	*x*
LE000016.H05	RE000016.H05	850	415		1.2	Al	*f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.H05	RE000002.H05	364	15		0.5	Al	
LE000003.H05	RE000003.H05	493	-2		0.7	stainless steel	*2,e*
AE000003.H05	BE000003.H05	493	-2			Al	*1,2,l*
LE000004.H05	RE000004.H05	47	197		0.7	Al	*w*
LE000005.H05	RE000005.H05	64	326		0.5 x 0.9	Al	*d,w*
LE000006.H05	RE000006.H05	360	140		0.5	Al	*y*
LE000007.H05	RE000007.H05	755	140		0.5	Al	*3*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000008.H05	RE000008.H05	715	155		0.9	Al	
LE000009.H05	RE000009.H05	428	230		0.5	Al	
LE000010.H05	RE000010.H05	465	265		0.5	Al	
LE000011.H05	RE000011.H05	492	295		0.6	Al	
LE000012.H05	RE000012.H05	605	310		0.6	Al	
LE000013.H05	RE000013.H05	645	310		0.6	Al	
LE000014.H05	RE000014.H05	680	228		0.5	Al	
LE000015.H05	RE000015.H05	775	230		0.6	Al	*d*
LE000017.H05	RE000017.H05	760	545		0.7	Al	
LE000018.H05	RE000018.H05	110	450		0.9	Al	
LE000019.H05	RE000019.H05	290	440		0.6	Al	
LE000020.H05	RE000020.H05	265	635		0.8	Al	
LE000021.H05	RE000021.H05	460	640		0.6	Al	
LE000022.H05	RE000022.H05	440	505		0.5	Al	
LE000023.H05	RE000023.H05	555	375		0.7	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Image of debris and secondary craters from feature LE000003.H05.
2 - Image rotated 30° counter-clockwise.
3 - Incorrect coordinates (X = 715, Y = 155) entered with image file.
4 - Feature located on Bolt H05C02B.
5 - Feature located on Bolt H05C06C.

OTHER PHOTODOCUMENTATION:

Pre-Flight - L-83-06439
On-Orbit - S32-75-64
Pre-Deintegration - KSC-390C-833.02, KSC-390C-1039.01, KSC-390C-1030.04
Post Deintegration - KSC-390C-2367.04, KSC-390C-1701.01, KSC-390C-1701.02
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - H05C02, H05C03, H05C06, H05C011, and H05C012
Clamp Bolts - H05S02B and H05S06C

ACCOMPANYING FIGURES:

See Figure A05-1.

LDEF LOCATION: H06
EXPERIMENT IDENTIFICATION: A0038
EXPERIMENT TITLE: INTERSTELLAR-GAS EXPERIMENT
PRINCIPAL INVESTIGATOR: D. LIND

PHYSICS DEPARTMENT
UTAH STATE UNIVERSITY
LOGAN, UTAH 84322-4415

SUMMARY OF OBSERVATIONS

Bay H06 contained the Interstellar-Gas Experiment (A0038), and was one of four 12"-deep (30.5 cm), active experiment trays (two peripheral [E12 and F06] and two space-end [H06 and H09]) designed to collect interstellar-gas atoms within metal foils at various times and locations around the Earth. In addition to particle collection, the experiment called for the isotopic analyses on recovered particles in the hopes of revealing the composition of the interstellar wind. The experiment exposed 15 μm thick, high-purity Copper-Beryllium (Cu-Be) collecting foils (five per detector) which were housed within 6061-T6 aluminum detector boxes; underlying each foils was a sulfuric acid anodized aluminum plate (6061-T6) which was, in most cases, in contact with the foil. Each detector possessed a viewing angle of between 35° and 41°, and was capped by electron- and high-voltage ion suppression grids (Monel) and a series of aluminum neutral-particle baffles. In general, there were two such units per A0038 experiment tray; Bay F06 housed only one such detector. Unfortunately, the active sequencing of the foils did not function properly for what is believed to have been grounding problems. The experiment base-support hardware consisted of various sized, 6061-T6 aluminum plates (0.1875" [4.7 mm] thick). In addition, the space-facing trays (H06 and H09) had four sulfuric acid anodized aluminum "L"-frames attached to the experiment-tray flanges. The aluminum housings, the base support plates, and the inner experiment-tray walls were painted with Chemglaze A276 white paint; Chemglaze Z306 black paint was used on the interior of the housings and baffles, and on the backside of the experiment tray for thermal control.

Following the M&D SIG A-Team surveys of the all integrated experiment tray associated with the A0038 experiment, the Cu-Be detection foils were removed by the Principal Investigator from their aluminum housings and examined in detail by the M&D SIG A-Team for penetrations/craters. Most of the foil penetrations and resulting craters in the underlying aluminum substrate exhibited a rather interesting morphologic relationship. The underlying craters were commonly offset from the penetration hole suggesting the projectile's path to be at some angle to the normal of the foil's surface. The foils themselves were generally raised off of the aluminum substrate as the result of the penetration/crater-forming event. Morphologically, these features resemble small volcanic cone structures. Features examined which were located in the various pieces of aluminum hardware associated with the experiment tray and experimental hardware were typical of feature produced in aluminum targets under controlled laboratory conditions. Painted aluminum surfaces commonly exhibited paint spall zones in association with the crater.

The M&D SIG survey visually identified a total of 146 impact features on all associated H06 experiment-tray surfaces. These surfaces included the experiment-tray flanges and walls, the experiment-tray clamps, bolts, and shims, and the exposed experimental surfaces. Sixty five features <0.5 mm in diameter were identified in various aluminum surfaces, but were not identified as to there precise locations (*e.g.*, experiment-tray flanges or experimental surface). Thirteen features were identified on the various experimental surfaces. Of these, nine represented impacts into aluminum surfaces, four of which were <0.5 mm in diameter (two in the frames supporting the Cu-Be foils), and five which were between 0.5 mm and 1.0 mm in diameter. The remaining four features represented impacts into the CU-Be foils (three which were <0.3 mm in diameter, and one which was between 0.3 mm and 1.0 mm in diameter. Two of the three <0.3 mm features in the Cu-Be foils were photodocumented. Twenty four features were identified on the experiment-tray flanges and experiment L-frames. Fifteen of these resided on the experiment L-frames (ten of which were <0.3 mm in diameter, four

which were between 0.5 mm and 1.0 mm in diameter, and one which measured ~1.3 mm in diameter). The remaining nine features were all found on the experiment-tray flanges (three which were <0.3 mm in diameter, four which were between 0.5 mm and 1.0 mm in diameter, one which measured ~1.4 mm in diameter, and one which measures ~1.5 mm in diameter. On the experiment-tray clamps and bolts, 41 of the 42 features identified were impact craters, all but one were <0.5 mm in diameter (seven of which were photodocumented, three of these on bolts); the one remaining feature was an ejecta spray pattern only.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			3	3
>0.3 mm			1	1
<0.5 mm	40		4	125*
>0.5 mm	1	11	5	17
TOTALS	41		13	146

* The locations of the "Too Smalls" were not documented.

The largest impact features identified were (1) an ~0.6 mm diameter crater located on the experiment-tray surface, (2) an ~0.4 mm diameter feature in the Cu-Be foils, (3) an ~1.5 mm diameter crater in the experiment-tray flanges, (4) an ~1.3 mm diameter crater in the L-frame, and (5) an ~0.5 mm diameter crater on an experiment-tray clamp.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection of Bay H06 was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft. This inspection identified no features which might be damaged or destroyed by attachment of the experiment-tray cover. However, one feature, an ejecta spray pattern on the outer edge of the left experiment-tray flange, would be covered by the experiment-tray rotator clamping mechanism. This ejecta spray pattern was caused by an impact into an experiment L-frame. One feature each was identified on clamps C01, and C03, two features were identified on clamp C07, and an ejecta spray pattern was identified on clamp C08 which was caused by an impact into an experiment-tray L-frame.

GENERAL FRONT AND BACKSIDE:

The general front and backside inspections were performed on March 5, 1990 when the experiment-tray was removed from LDEF and prior to attaching the experiment-tray to the rotator. There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.125" (3.2 mm) thick experiment-tray flanges.

DOCUMENTATION:

The detailed examination and photodocumentation of the H06 L-frames was conducted on February 23, 1990 after their removal from the experiment tray which was still mounted on LDEF. This examination was performed utilizing M&D SIG System #3; the coordinates for features residing on the L-frames were measured using a metric tape measure. The detailed examination and photodocumentation of the integrated experiment tray from Bay H06 was conducted on March 5 and 6, 1990 in the vertical position utilizing M&D SIG System #1 and Coordinate Registration System #2. The Cu-Be foils were examined and photodocumented, after deintegration from the experiment tray, utilizing M&D SIG System #3 and the coordinates were measured using a metric scale. The bolts, clamps, and shims associated with this tray were

scanned and imaged with M&D SIG System #3; the coordinates for features residing on the clamps were measured with a metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC010001.H06	RC010001.H06	45	43		0.4	Al	*1*
LC010002.H06	RC010002.H06	12	11		0.4	Al	*1*
LC020001.H06	RC020001.H06	53	49		0.2	Al	
LC020002.H06	RC020002.H06	97	7		0.3	Al	
LC030001.H06	RC030001.H06	83	8		0.3	Al	
LC100001.H06	RC100001.H06	46	49		0.5	Al	
LC120001.H06	RC120001.H06	20	5		0.3	Al	

Impact Features Imaged on Experiment-Tray Flanges, Walls and L-Frames

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LF010001.H06	RF010001.H06	568	1		0.7	Al	*2*
LF010002.H06	RF010002.H06	645	15		0.5	Al	*2*
LF010003.H06	RF010003.H06	527	0	21	0.8	Al (pinted)	*3*
LF010004.H06	RF010004.H06	616	0		0.5	Al	*3*
LF020001.H06	RF020001.H06	3	168		0.4 x 0.8	Al	*2*
LF020002.H06	RF020002.H06	0	660	20	0.4	Al (pinted)	*4*
LF020003.H06	RF020003.H06	0	488	5	0.5	Al (pinted)	*4*
LF030001.H06	RF030001.H06	267	0	19	0.5	Al (pinted)	*3*
LF030002.H06	RF030002.H06	434	0	7	1.3	Al (pinted)	*3,5,e,h*
LF030003.H06	RF030003.H06	727	0	7	0.5	Al (pinted)	*3*
LF030004.H06	RF030004.H06	728	0	10	0.5	Al (pinted)	*3*
LF040001.H06	RF040001.H06	11	743		0.5 x 0.6	Al	*2*
LF040002.H06	RF040002.H06	13	714		0.3	Al	*2*
LF040003.H06	RF040003.H06	15	670		0.4	Al	*2*
LF040004.H06	RF040004.H06	0	458	17	0.5	Al (pinted)	*4*
LE000003.H06	RE000003.H06	0	740	120	0.5 (1.0)	Al (pinted)	*6,7,b,f*
LE000004.H06	RE000004.H06	0	585	168	1.4 (1.7)	Al (pinted)	*6,8,b,f*
LE000007.H06	RE000007.H06	625	845	10	1.5 (1.9)	Al (pinted)	*6,9,b,f*
LE000008.H06	RE000008.H06	185	845	125	0.5 (1.1)	Al (pinted)	*6,10,b,f*
LE000010.H06	RE000010.H06	663	845		0.8	Al	*11*
LE000011.H06	RE000011.H06	432	845		0.5 (0.7)	Al (pinted)	*6,8,b,f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.H06	RE000001.H06	164	640		0.5	Al	*g*
LE000002.H06	RE000002.H06	340	495		0.4 (1.3)	Al (pinted)	*6,b,g*
LE000005.H06	RE000005.H06	765	325	112	0.5 (1.2)	Al (pinted)	*6,9,12,b,g*
LE000006.H06	RE000006.H06	500	815		0.6 (2.1)	Al (pinted)	*6,13,b*
LE000009.H06	RE000009.H06	670	485		0.6 (1.6)	Al (pinted)	*6,14,b*

LE030001.H06	RE030001.H06	217	82	0.4 (1.1)	Cu-Be	*15,w*
LE030002.H06	RE030002.H06	199	64	0.2 (0.4)	Cu-Be	*16,w*
LE030003.H06	RE030003.H06	72	215	0.3 (0.6)	Cu-Be	*15,w*
AE030003.H06	BE030003.H06	72	215	0.3 (0.6)	Cu-Be	*15,17,w*
LM000001.M00	RM000001.M00	0	0	1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0	2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0	4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0	9.7	micrometer	*q*

1 - Wrong clamp number (C01) input into image file; correct clamp designation is C04.
2 - Feature located on space-facing side of L-frame.
3 - Feature located on Row 9 (leading-edge) facing side of L-frame.
4 - Feature located on Row 12 facing side of L-frame.
5 - This impact caused the spray pattern on clamp C08.
6 - Number in parentheses is the diameter of associated spall zone.
7 - Image taken at ~30° to left from normal of crater.
8 - Image taken at ~45° to left from normal of crater.
9 - Image taken at ~60° above normal of crater.
10 - Image taken at ~30° above normal of crater.
11 - Image taken at ~10° above normal of crater.
12 - Feature located on back fin of neutral-particle baffle inside Cu-Be foil housing.
13 - Image taken at ~75° above normal of crater; Feature located on bottom outside wall of experiment foil housing.
14 - Incomplete front surface spallation of white paint; Feature located on lower lip of Cu-Be foil housing.
15 - Number in parentheses is diameter of the area around crater were the Cu-Be foil was peeled back from the aluminum substrate.
16 - Number in parentheses is the diameter of the base of volcano-like bulge in the Cu-Be foil.
17 - Second image taken of same feature because first image had vibrations.

OTHER PHOTODOCUMENTATION:

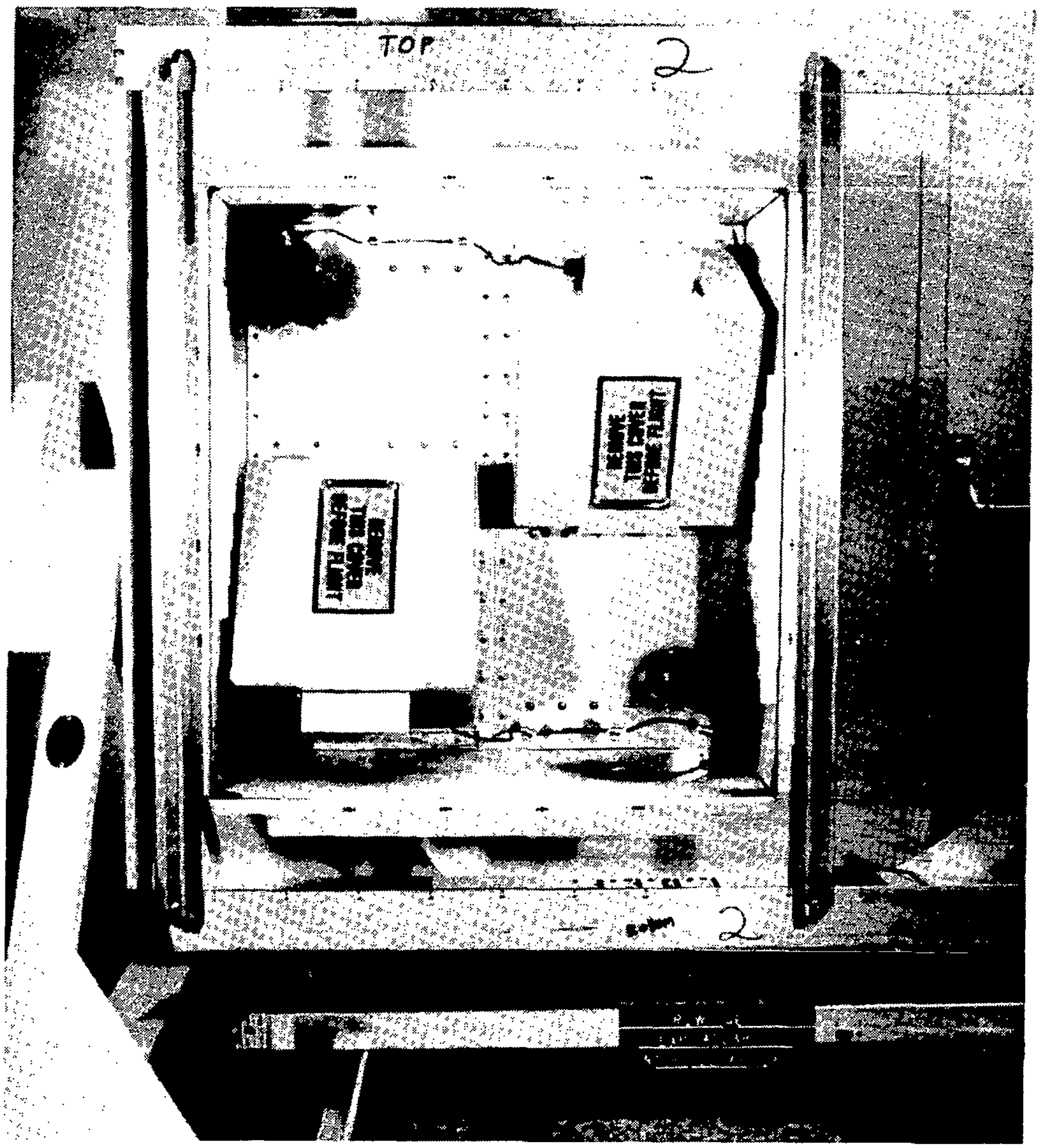
Pre-Flight - 108-KSC-384C-538/8
On-Orbit - S32-75-63
Pre-Deintegration - KSC-390C-1030.04, KSC-390C-833.02, KSC-390C-1030.02
Post Deintegration - KSC-390C-1641.03
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - H06C01, H06C02, H06C03, H06C08, H06C10, and H06C12
Clamp Bolts - H06S02C and H06S04A
Other - H06F01 - L-frame
H06F03 - L-frame

ACCOMPANYING FIGURES:

Figure H06-1. This post-deintegration view shows the front of the entire H06 experiment tray. The space-exposed interstellar-gas collector foils have been covered in this view.


TOP
2
2

LDEF LOCATION: H07
EXPERIMENT IDENTIFICATION: A0133
EXPERIMENT TITLE: EFFECT OF SPACE ENVIRONMENT ON SPACE-BASED RADAR PHASED-ARRAY ANTENNA

PRINCIPAL INVESTIGATOR: R. DEIASI
A08-35
GRUMMAN AEROSPACE CORPORATION
BETHPAGE, NEW YORK 11714

SUMMARY OF OBSERVATIONS

Bay H07 held a partially active, 6"-deep (15.2 cm) experiment tray containing the Effect Of Space Environment On Space-Based Radar Phased-Array Antenna experiment (A0133). The overall objective of the A0133 experimental package was to evaluate the effects of the near-Earth space environment on various polymeric materials being considered for use in larger space structures. The passive portion of the experimental surface consisted of sixteen 0.5" (1.3 cm) and eight 1.0" (2.4 cm) wide, by 10" (25.4 cm) long strips of spliced and continuous Kapton, both plain and reinforced, which were under tension (30, 150, 300, and 450 psi); half of each specimen was partially shadowed. The active portion of the experimental package (14" x 28"; 35.6 x 71 cm) was designed to address the effects of interaction between high voltage and plasma in low-Earth orbit. This section of the experiment tray was covered with the Grumman Space-Based Radar Phased-Array Antenna (SBR) which consisted of two Kapton antenna planes with thin copper electrodes (1 and 2 KeV potential between electrodes), and a perforated aluminum ground plane. Surrounding the exposed SBR was a 2" (5.1 cm) wide 6061-T6, black-painted aluminum frame, while several inches below the SBR was an aluminum baseplate.

Observed features in the aluminum and stainless steel surfaces were typical of craters formed in similar materials under controlled laboratory conditions. Kapton materials possessed craters, penetrations, and impact-induced delamination characteristics commonly seen in association with this material, while painted surfaces exhibited spall zone in the surrounding paint (see Section 2.B).

There were a total of 206 features visually identified on the H07 experiment-tray hardware and experimental surfaces, 190 of which were smaller in size than the M&D SIG photodocumentation threshold (<0.5 mm or <0.3 mm in diameter for craters and penetrations holes, respectively). Forty three of these features were located on the various experiment-tray clamps or flanges (21 and 22, respectively), while the remaining 147 were identified on various experimental surfaces (65 on aluminum surfaces and 82 on the various Kapton surfaces). The remaining three features on the clamps were between 0.5 mm and 1.0 mm in diameter and, along with an ~1.3 mm in diameter feature on bolt C11A were photodocumented. Four features were photodocumented on the experiment-tray flanges, of which two were between 0.5 mm and 1.0 mm in diameter, one measured ~1.4 mm in diameter, and one measured ~2.0 mm in diameter. Two features were photodocumented on the aluminum experimental surfaces (~1.1 mm and ~1.5 mm in diameter), while six were photodocumented on the various Kapton surfaces, all of which were between 0.5 mm and 1.0 mm in diameter.

The largest features identified on this tray were (1) an ~2.0 mm in diameter feature on the experiment-tray flange, (2) an ~1.5 mm in diameter feature (LE000004.H07) on the aluminum SBR screen, and (3) an ~0.9 mm in diameter feature (LE000007.H07) on a Kapton surface.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	21	22	147	190
>0.5 mm	4	4	8	16
TOTALS	25	26	155	206

M&D SIG INSPECTIONS

PRE-DEINTEGRATION:

Eight features (three on the experiment-tray flanges, four on experiment-tray clamps, and one on bolt C11A) were identified during the pre-deintegration inspection of Bay H07 conducted on February 21, 1990. All three features on the experiment-tray flanges were in areas that would be contacted by the experiment-tray cover, but only one of these warranted cutting the experiment-tray cover gasket. One ~1.0 mm in diameter feature was identified on a bolt C11A, and the use of an appropriate tool and caution was requested from Ground Operation personnel when removing this bolt.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (30.5 mm) thick, chromic-anodized 6061-T6 experiment-tray flanges.

DOCUMENTATION:

Tray H07 arrived in the M&D SIG area on one of the JSC rotators precluding the use of an M&D SIG Coordinate Registration System. All hardware associated with the H07 experiment tray was inspected and imaged on March 14, 1990, utilizing M&D SIG System #3; the experiment tray was inspected in the vertical position. Coordinates for photodocumented features were determined using a metric tape measure or scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LC080001.H07	RC080001.H07	86	49		0.7	Al	
LC100001.H07	RC100001.H07	38	81		0.6	Al	
LC120001.H07	RC120001.H07	33	80		0.7	Al	
LS110001.H07	RS110001.H07	ND	ND		1.3	stainless steel	*3*

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.H07	RE000001.H07	20	262		2.0	Al	*1*
LE000002.H07	RE000002.H07	20	178		0.7	Al	*2*
LE000011.H07	RE000011.H07	20	625		0.6	Al	
LE000012.H07	RE000012.H07	20	669		1.4	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000003.H07	RE000003.H07	270	225		0.4 x 0.6	Kapton	*b*
LE000004.H07	RE000004.H07	430	290		1.6	Al	
LE000005.H07	RE000005.H07	440	340		0.4	Kapton	*c*
LE000006.H07	RE000006.H07	640	430		0.5	Kapton	*b*
LE000007.H07	RE000007.H07	255	530		0.9	Kapton	*c*
LE000008.H07	RE000008.H07	770	565		1.1	Al	
LE000009.H07	RE000009.H07	110	640		0.4	Kapton	*4*
LE000010.H07	RE000010.H07	420	715		0.5	Kapton	*4*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Incorrect coordinates (X = 20, Y = 178) entered with image file.
2 - Crater lip is broken.
3 - Feature located on bolt C11A.
4 - Penetration through tape into underlying substrate.

OTHER PHOTODOCUMENTATION:

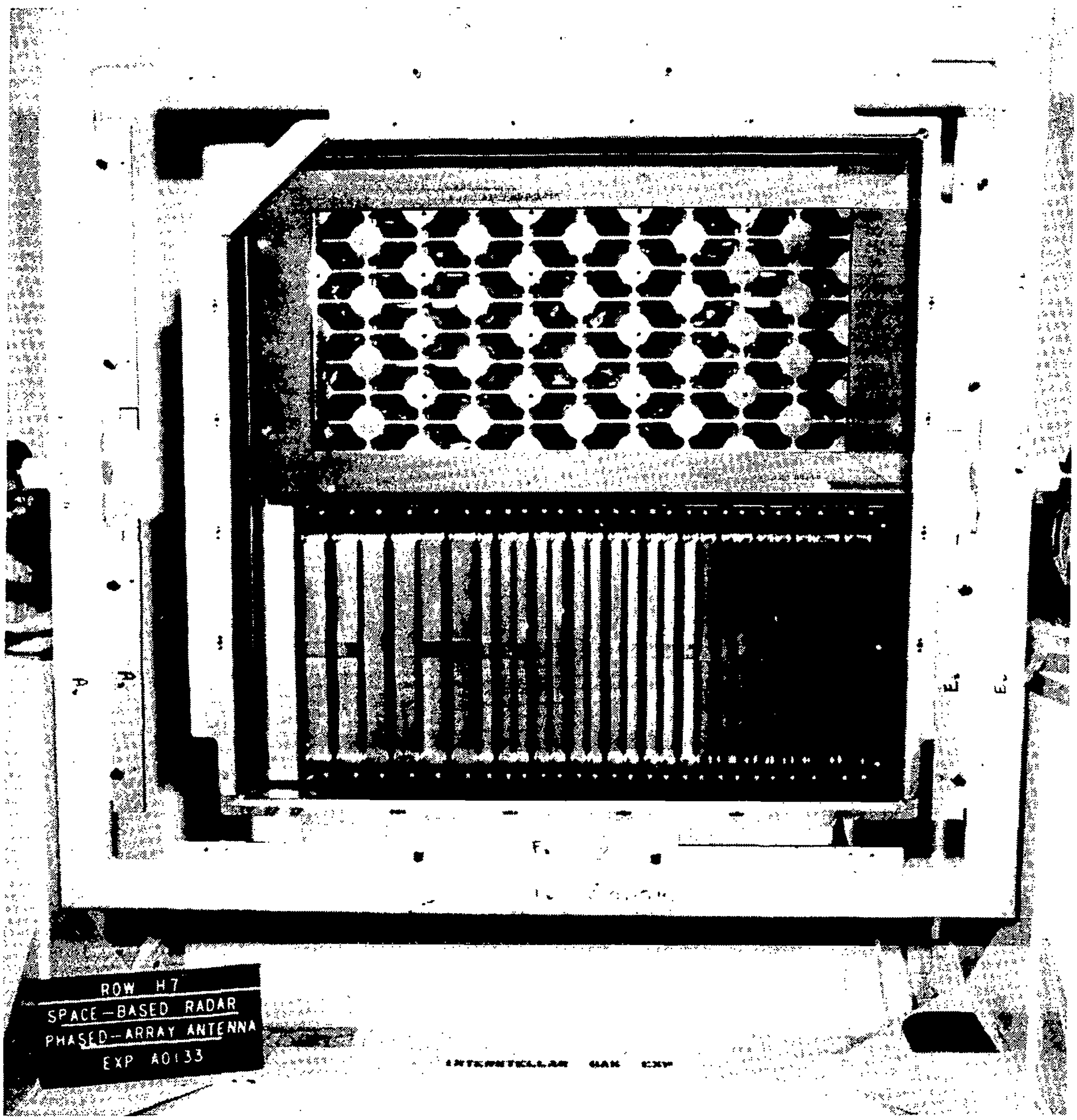
Pre-Flight - L-89-4390
On-Orbit - S32-75-027
Pre-Deintegration - KSC-390C-833.02, KSC-390C-1030.03, KSC-390C-1030.04
Post Deintegration - KSC-390C-1990.01, KSC-390C-1991.05
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - H07C01, H07C04, H07C06, H07C08, H07C10, and H07C12
Clamp Bolts - H07S11A

ACCOMPANYING FIGURES:

Figure H07-1. This post-deintegration view shows the front of the entire H07 experiment tray.


ROW H7
SPACE-BASED RADAR
PHASED-ARRAY ANTENNA
EXP A0133

LDEF LOCATION: H09
EXPERIMENT IDENTIFICATION: A0038
EXPERIMENT TITLE: INTERSTELLAR-GAS EXPERIMENT
PRINCIPAL INVESTIGATOR: DON L. LIND
PHYSICS DEPARTMENT
UTAH STATE UNIVERSITY
LOGAN, UTAH 84322-4415

SUMMARY OF OBSERVATIONS

Bay H09 contained the Interstellar-Gas Experiment (A0038), and was one of four 12"-deep (30.5 cm), active experiment trays (two peripheral [E12 and F06] and two space-end [H06 and H09]) designed to collect interstellar-gas atoms within metal foils at various times and locations around the Earth. In addition to particle collection, the experiment called for the isotopic analyses on recovered particles in the hopes of revealing the composition of the interstellar wind. The experiment exposed 15 μm thick, high-purity Copper-Beryllium (Cu-Be) collecting foils (five per detector) which were housed within 6061-T6 aluminum detector boxes; underlying each foils was a sulfuric acid anodized aluminum plate (6061-T6) which was, in most cases, in contact with the foil. Each detector possessed a viewing angle of between 35° and 41°, and was capped by electron- and high-voltage ion suppression grids (Monel) and a series of aluminum neutral-particle baffles. In general, there were two such units per A0038 experiment tray; Bay F06 housed only one such detector. Unfortunately, the active sequencing of the foils did not function properly for what is believed to have been grounding problems. The experiment base-support hardware consisted of various sized, 6061-T6 aluminum plates (0.1875" [4.7 mm] thick). In addition, the space-facing trays (H06 and H09) had four sulfuric acid anodized aluminum "L"-frames attached to the experiment-tray flanges. The aluminum housings, the base support plates, and the inner experiment-tray walls were painted with Chemglaze A276 white paint; Chemglaze Z306 black paint was used on the interior of the housings and baffles, and on the backside of the experiment tray for thermal control.

Following the M&D SIG A-Team surveys of the all integrated experiment tray associated with the A0038 experiment, the Cu-Be detection foils were removed by the Principal Investigator from their aluminum housings and examined in detail by the M&D SIG A-Team for penetrations/craters. Most of the foil penetrations and resulting craters in the underlying aluminum substrate exhibited a rather interesting morphologic relationship. The underlying craters were commonly offset from the penetration hole suggesting the projectile's path to be at some angle to the normal of the foil's surface. The foils themselves were generally raised off of the aluminum substrate as the result of the penetration/crater-forming event. Morphologically, these features resemble small volcanic cone structures. Features examined which were located in the various pieces of aluminum hardware associated with the experiment tray and experimental hardware were typical of feature produced in aluminum targets under controlled laboratory conditions. Painted aluminum surfaces commonly exhibited paint spall zones in association with the crater.

The M&D SIG survey visually identified a total of 67 impact features on all associated H09 experiment-tray surfaces. These surfaces included the experiment-tray flanges and walls, the experiment-tray clamps, bolts, and shims, and the exposed experimental surfaces. Seventeen features <0.5 mm in diameter were identified in various aluminum surfaces, but were not identified as to there precise locations *(e.g.,* experiment-tray flanges or experimental surface). Eleven features were identified on the various experimental surfaces. Of these, five were located in various aluminum surfaces (two <0.5 mm in diameter, two were between 0.5 mm and 1.0 mm in diameter, and one which measured ~1.8 mm in diameter), and six were located in the Cu-Be foils and were <0.3 mm in diameter, only one of which was photodocumented. Of the 20 features which were identified and photodocumented on the experiment-tray flanges and L-frames, 12 were <0.5 mm in diameter (ten on the L-frames and two on the experiment-tray walls), seven were between 0.5 mm and 1.0 mm in diameter (five on the L-frames, and one was on the experiment-tray wall), and one which measured ~1.1 mm in diameter was

located on an L-frame. Nineteen features were identified on the various clamps and bolts associated with the H09 experiment tray, 16 of which were <0.5 mm in diameter on the various clamps (two of which were photodocumented), and one <0.5 mm in diameter feature on bolt C02B, and one feature each on clamps C07 and C11 which were >0.5 mm in diameter (~0.7 mm and ~0.6 mm in diameter, respectively).

During the detailed survey of the Cu-Be foils from cassettes #5 and #6 (M&D SIG Component Numbers E05 and E06) only two features were photodocumented (one in the Cu-Be foil of Cassette #5 [~0.2 mm in diameter] and one in the aluminum frame around the Cu-Be foil of Cassette #6 [~0.6 mm in diameter]). In addition, the examination of the Cu-Be foil from Cassette #6 revealed the presence of numerous elongate features within the foil which were <50 μm in diameter. An inspection of the detector housing for this cassette revealed an impact on the inner wall which was the apparent source of the ejecta which generated these small, oblique features in the Cu-Be foil. These small features were not counted or photodocumented, and are not included in the Feature Summary table.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	17			54•
>0.5 mm	2	8	3	13
TOTALS	19			67

• The locations of the "Too Smalls" were not documented.

The largest features identified were (1) an ~1.8 mm in diameter on an aluminum experimental surface, (2) an ~0.2 mm in diameter feature in the Cu-Be foils, (3) an ~0.7 mm in diameter feature in an experiment-tray flange, (4) an ~1.1 mm in diameter feature an L-frame, and (5) an ~0.7 mm in diameter feature on an experiment-tray clamp.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection of Bay H09 was conducted on February 21, 1990 while the experiment-tray was mounted on the spacecraft. This inspection identified five features which might be damaged or destroyed by attachment of the experiment-tray cover; no features were identified in the areas which would be affected by the experiment-tray rotator clamping mechanism. In an effort to protect the most interesting feature within the experiment-tray cover area, the cover gasket was cut in one location to prevent it from coming into contact with this feature, and to provide a stand-off distance between the experiment-tray cover and flanges. One feature each was identified on clamps C04, C07, and C09, two were identified on clamp C03, four were identified on clamp C11, and five features were identified on clamp C02.

GENERAL FRONT AND BACKSIDE:

The general front and backside inspection was performed on March 5, 1990 after the experiment-tray had been removed from LDEF, but prior to placing the tray within a experiment-tray rotator. There were no noticeable penetrations, bulges, or spallation features on the 0.125" (30.5 mm) thick, chromic-anodized 6061-T6 experiment-tray flanges.

DOCUMENTATION:

The detailed examination and photodocumentation of the L-frames from the H09 tray was conducted on February 22 and 23, 1990 following their removal from the integrated experiment tray which was still mounted on LDEF, and was carried out utilizing M&D SIG System #3. The detailed examination and

photodocumentation of the integrated H09 tray was conducted on March 5 and 6, 1990 in the vertical position utilizing M&D SIG System #1. The Cu-Be foils were examined and photodocumented on March 7, 1990, following their deintegration from the detector housing, utilizing M&D SIG System #3. The bolts, clamps, and shims associated with this tray were scanned and imaged with M&D SIG System #3. The coordinates for all features were measured with a metric tape measure or scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC010001.H09	RC010001.H09	71	31		0.5	Al	
LC070001.H09	RC070001.H09	125	3	1	0.7	Al	*1*
LC090001.H09	RC090001.H09	90	30		0.5	Al	
LC110001.H09	RC110001.H09	30	25		0.6	Al	

Impact Features Imaged on Experiment-Tray Flanges, Walls and L-Frames

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LF010001.H09	RF010001.H09	0	198	12	0.3	Al	*2*
LF010002.H09	RF010002.H09	0	267	7	0.2 x 0.4	Al	*2*
LF010003.H09	RF010003.H09	0	845	6	0.4 x 0.6	Al	*2,3,j*
LF010004.H09	RF010004.H09	0	556	1	0.5	Al	*2*
LF020001.H09	RF020001.H09	260	0	8	0.3	Al	*4*
LF020002.H09	RF020002.H09	141	0	2	0.5	Al	*4*
LF020003.H09	RF020003.H09	147	13		0.7	Al	*5*
LF020004.H09	RF020004.H09	662	5		0.3	Al	*5*
LF030001.H09	RF030001.H09	10	558		0.3	Al	*5*
LF030002.H09	RF030002.H09	0	550	10	0.6	Al	*2*
LF030003.H09	RF030003.H09	0	460	5	0.4 x 0.5	Al	*2*
LF030004.H09	RF030004.H09	0	38	15	0.8	Al	*2*
LF040001.H09	RF040001.H09	783	14		0.4	Al	*5*
LF040002.H09	RF040002.H09	185	0	3	0.4	Al	*6*
LF040003.H09	RF040003.H09	10	0	10	0.3	Al	*6*
LF040004.H09	RF040004.H09	100	0	23	1.1	Al	*4*
LE000001.H09	RE000001.H09	409	-10		0.7	Al	
LE000004.H09	RE000004.H09	770	35	70	0.4 (1.6)	Al	*7,8,9,10,11,f*
LE000005.H09	RE000005.H09	770	125	25	0.4 (2.1)	Al	*7,8,9,11,f*
LE000006.H09	RE000006.H09	770	625	23	0.6 (1.0)	Al	*7,8,9,11,f*

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000002.H09	RE000002.H09	423	565		1.8	Al	*11,12*
LE000003.H09	RE000003.H09	195	660		0.7 (2.0)	Al	*7,11,13,b,k*
LE050001.H09	RE050001.H09	170	97		0.2	Cu-Be	*14,w*
LE060001.H09	RE060001.H09	10	110		0.6	Al	*15,w*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Feature located on side of clamp.
2 - Feature located on Row 9 (leading edge) facing side of L-frame.
3 - Two distinct sub-craters visible in this feature.
4 - Feature located on Row 6 facing side of L-frame.
5 - Feature located on space-facing side of L-frame.
6 - Feature located on Row 12 facing side of L-frame.
7 - Number in parentheses is the diameter of spall zone in white paint around crater.
8 - Wrong X-coordinate (X = 77) input into image file.
9 - Image taken at ~55° above normal to crater.
10 - Wrong angle (60°) input into image file.
11 - Left and right images are 180° out of phase with each other.
12 - Feature located on top edge of experiment foil housing.
13 - Two melt beads visible in bottom of crater.
14 - Feature located on second experiment foil layer.
15 - Feature located on aluminum frame supporting the Cu-Be foil.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-538/6
On-Orbit - S32-75-61
Pre-Deintegration - KSC-390C-1030.04, KSC-390C-833.02, KSC-390C-833.01
Post Deintegration - KSC-390C-1636.10, KSC-390C-1726.01 through KSC-390C-1726.05
M&D SIG Photos - None

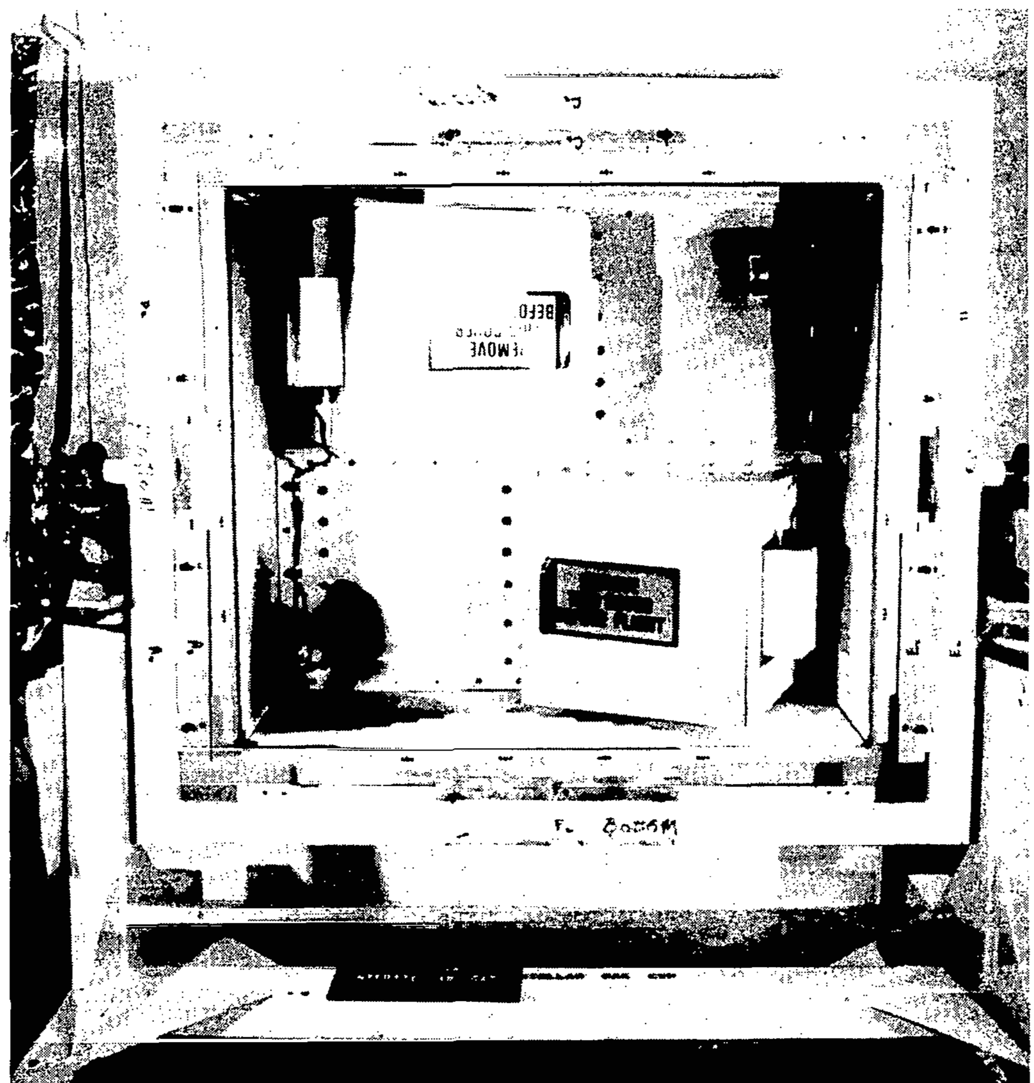
ARCHIVED MATERIALS:

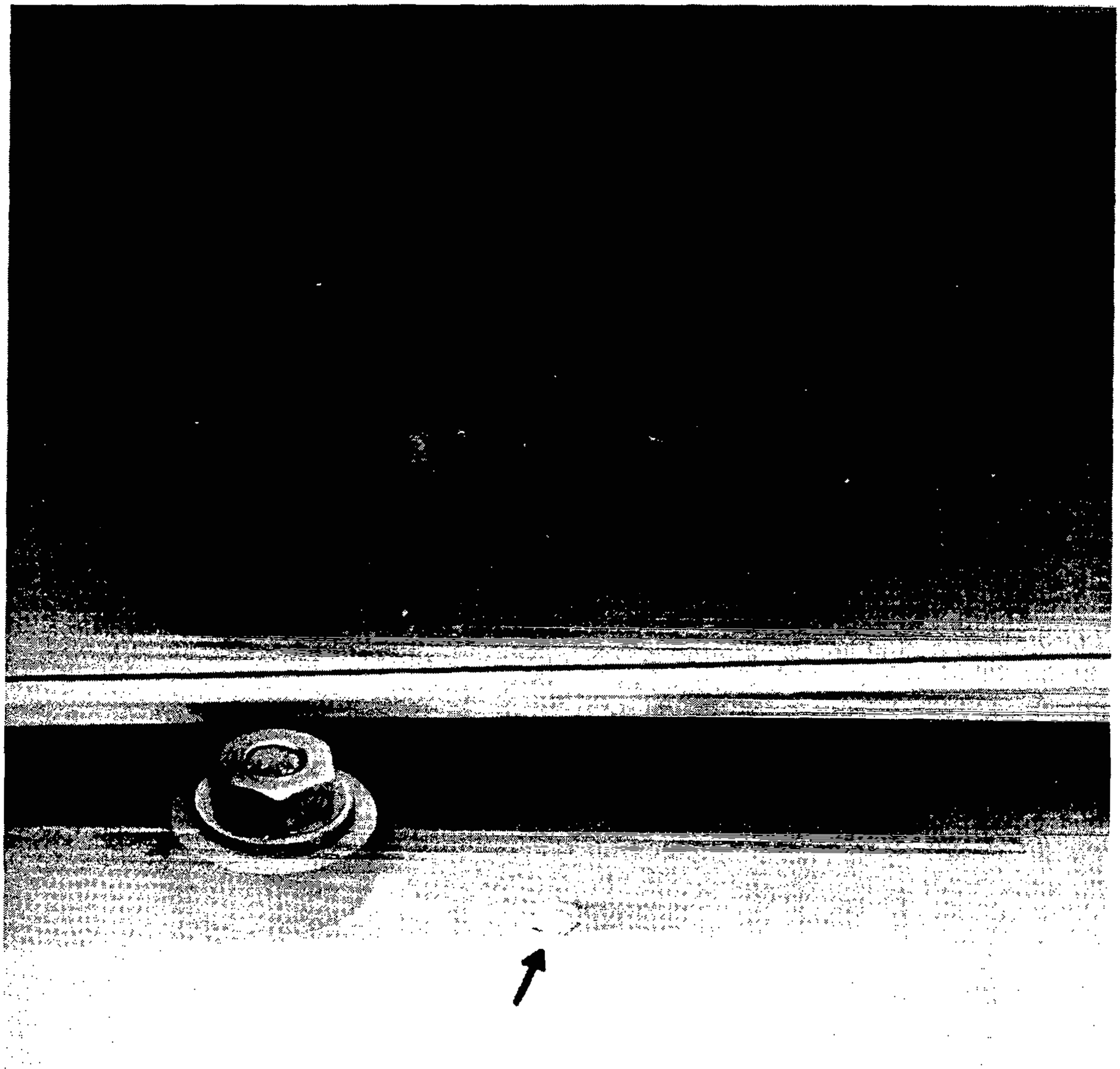
Clamps - H09C01, H09C02, H09C07, and H09C09
Clamp Bolts - H09S02B
Other - H09F03 - L-frame
LD-9 Core from experiment tray bottom containing Feature #10.
LD-10 - Core from experiment tray bottom containing Feature #3 with melt beads.
LD-11 - Core from experiment tray bottom containing Feature #7.
LD-12 - Core from experiment tray bottom containing Feature #8.
LD-13 - Core from experiment tray bottom containing Feature #9.

ACCOMPANYING FIGURES:

Figure H09-1. This post-deintegration view shows the front of the entire H09 experiment tray. The space-exposed interstellar-gas collector foils have been covered in this view.

Figure H09-2. View of a crater (indicated by arrow) located in aluminum with a large adjacent ejecta pattern. The feature was located inside one of the detector housings. This view measures approximately 12 cm across.





LDEF LOCATION: H11
EXPERIMENT IDENTIFICATION: A0023
EXPERIMENT TITLE: MULTIPLE-FOIL MICROABRASION PACKAGE
PRINCIPAL INVESTIGATOR: J.A.M. McDONNELL
UNIVERSITY OF KENT
CANTERBURY, UNITED KINGDOM

EXPERIMENT IDENTIFICATION: A0201
EXPERIMENT TITLE: INTERPLANETARY DUST EXPERIMENT
PRINCIPAL INVESTIGATOR: F. SINGER
UNIVERSITY OF VIRGINIA
CHARLOTTESVILLE, VIRGINIA

SUMMARY OF OBSERVATIONS

Bay H11 contained a passive, 3"-deep (7.6 cm) experiment tray that housed two meteoroid/debris-type experiments (the Multiple-Foil Microabrasion Package [A0023] and the Interplanetary Dust Experiment [A0201]). The A0023 experiment was designed to measure the density (flux), size, velocity, radial distribution, and composition of micro-particles in low-Earth orbit. The detectors exposed rolled aluminum foils as thin as 1.5 μm which were bonded to etched aluminum grids for support. The experiment occupied two-thirds of Bay H11, as well as one third of four peripheral tray spaced at 90° intervals around the spacecraft (C03, C09, E06, and D12).

The remaining one third of Bay H11 held the Interplanetary Dust Experiment which also occupied portions of Bays C09, D06, G10, as well as all of Bay B12. This experimental package exposed metal-oxide-silicon (MOS), capacitor-type detectors to the near-Earth meteoroid/debris environment. The objective of the MOS detectors was to obtain mass and velocity information on the particles impinging upon their surfaces. Two varieties of detectors totaling ~1 m^2 of exposed surface area were flown on A0201; sixty percent of the detector surfaces possessed an oxide coating of 0.4 μm thick, while the remaining 40 percent had a 1.0 μm thick oxide coating. Each one-third tray typically contained 80 MOS detectors and one Sun sensor; the remainder of the A0201 experiment consisted of aluminum mounting rings on an aluminum baseplate.

Impact features residing in the various aluminum hardware associated with each of the experiments in Bay H11 were typical of hypervelocity impacts into aluminum produced under controlled laboratory conditions. Penetrations through the aluminum foils of A0023 varied from circular to elongate in shape; several penetration resembled tears and may not have resulted from the penetration of a hypervelocity particle. Impacts into the originally smooth MOS detectors exhibited somewhat complex morphologies. Generally, such impacts possessed a deep central pit; it was the diameter of this pit which was utilized by the M&D SIG A-Team for the 0.5 mm threshold criteria. Surrounding the central pits were spall zones possessing diameters on the order of 1.25 to 3 times that of the central pit. Fractures or cracks radiating from the central pit/spall zone were commonly found in association with the larger impacts into the amorphous metal-oxide-silicon material.

The M&D SIG survey identified a total of 146 features on all H11 experiment-tray surfaces, 135 of which were <0.5 mm in diameter (24 on the experiment-tray clamps, 22 on the experiment-tray flanges, and 89 on the various experimental surfaces). Fifteen features were photodocumented on the A0023 and A0201 experimental surfaces, some of which were <0.5 mm in diameter. Seven of these were located on the A0023 experiment and ranged in size from 0.2 mm to 1.0 mm in diameter. The remaining eight features were located on experiment A0201 and ranged in size from 0.4 mm to 0.8 mm in diameter. Two features were

photodocumented on the experiment-tray flanges, measuring ~0.6 mm and ~0.9 mm in diameter, respectively, and one feature was photodocumented which resided on clamp C03 and measured ~0.5 mm in diameter.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.5 mm	24	22	89	135
>0.5 mm	1	2	8	11
TOTALS	25	24	97	146

The largest impact features found on this tray were (1) an ~0.9 mm in diameter feature on the bottom experiment-tray flange, (2) an ~1.0 mm in diameter feature which was located on the baseplate of the A0023 experiment, and (3) an ~0.5 mm in diameter feature on clamp C03.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The initial inspection of Bay H11 was conducted on February 21, 1990 prior to the deintegration of the experiment tray from LDEF. None of the three features identified on the experiment-tray flanges during this inspection warranted alteration of the experiment-tray cover gasket.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.625" (1.6 mm) thick, experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of tray H11 was conducted on March 16, 1990 in the vertical position utilizing M&D SIG System #1. The clamps, bolts, and shims associated with this tray were examined with M&D SIG System #3; the coordinates for features all residing on these surfaces were measured with a small metric scale.

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC030001.H11	RC030001.H11	80	11		0.5	Al	
AC030001.H11	BC030001.H11	80	11		0.5	Al	

Impact Features Imaged on Experiment-Tray Flanges and Walls

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.H11	RE000001.H11	600	815		0.6	Al	
LE000014.H11	RE000014.H11	140	0		0.9	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000002.H11	RE000002.H11	150	625		0.5	MOS	*1,10,d*
LE000003.H11	RE000003.H11	150	510		0.4	MOS	*2,10,d*
LE000004.H11	RE000004.H11	178	505		0.4	MOS	*3,10,*
LE000005.H11	RE000005.H11	135	443		0.4	MOS	*4,10*
LE000006.H11	RE000006.H11	138	392		0.8	Al (Baseplate)	*5,10*
LE000007.H11	RE000007.H11	235	260		0.4	MOS	*6,10*
LE000008.H11	RE000008.H11	675	550		0.7	Al (Baseplate)	*9*
LE000009.H11	RE000009.H11	730	535		0.3 x 0.7	Al (Foil)	*9*
LE000010.H11	RE000010.H11	725	633		0.2	Al (Foil)	*7,9,d*
LE000011.H11	RE000011.H11	725	558		0.4 x 0.6	Al (Foil)	*9*
LE000012.H11	RE000012.H11	770	730		0.9	Al (Baseplate)	*9*
LE000013.H11	RE000013.H11	650	355		0.9	Al (Frame)	*9,12,d*
LE000015.H11	RE000015.H11	316	140		0.4	MOS	*8,10,11*
LE000016.H11	RE000016.H11	775	245		1.0	Al (Baseplate)	*9*
LE000017.H11	RE000017.H11	451	52	15	0.7	Al (Frame)	*10*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

MOS - Metal-oxide-silicon capacitor-type impact detectors

1 - Row 3, cell 2 MOS surface; two ejecta spray patterns are visible.
2 - Row 5, cell 2 MOS.
3 - Row 5, cell 3 MOS; diameter given is for penetration hole, spall zone measures ~1.1 mm.
4 - Row 6, cell 2 MOS.
5 - Wrong coordinates (X = 135, Y = 443) entered in image files.
6 - Row 8, cell 4 MOS; an ~1.2 mm spall zone is present.
7 - An ~1 mm spall zone is present.
8 - Row 10, cell 5 MOS; an ~1.1 mm spall zone is present.
9 - A0023
10 - A0201
11 - Wrong experiment number (A0023) entered in image files.
12 - Image taken at an ~15° from normal of crater.

OTHER PHOTODOCUMENTATION:

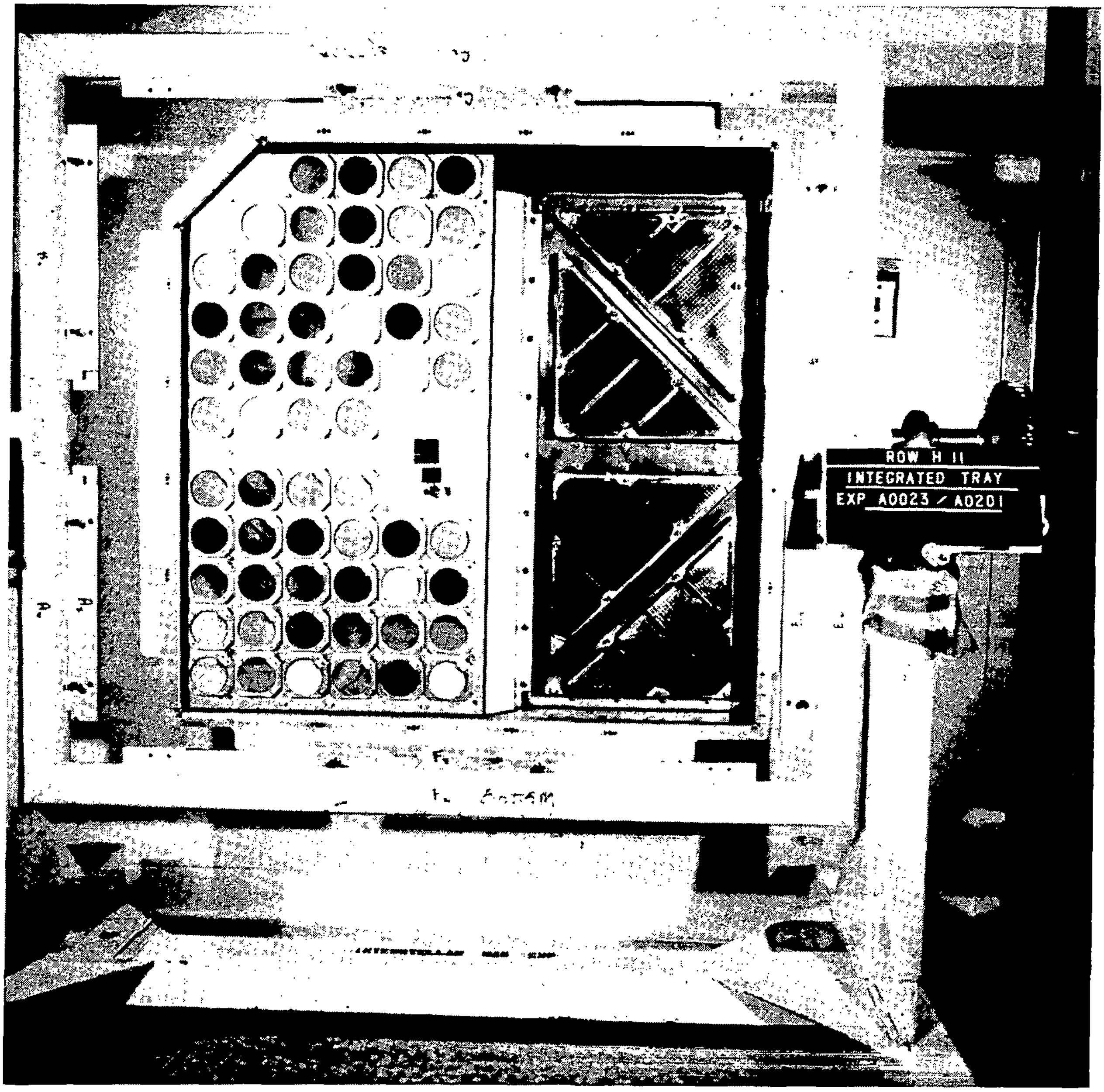
Pre-Flight - 108-KSC-384C-8/4
On-Orbit - S32-75-52
Pre-Deintegration - KSC-390C-1030.04, KSC-390C-833.02, KSC-390C-832.12
Post Deintegration - KSC-390C-2065.07, KSC-390C-2065.12
M&D SIG Photos - None

ARCHIVED MATERIALS:

Clamps - H11C01, H11C03, H11C05, H11C06, and H11C12
Clamp Bolts - H11S01C and H11S02B

ACCOMPANYING FIGURES:

Figure H11-1 - This post-deintegration view shows the front of the H11 integrated experiment tray.



LDEF LOCATION: H12
EXPERIMENT IDENTIFICATION: M0001
EXPERIMENT TITLE: HEAVY IONS IN SPACE
PRINCIPAL INVESTIGATOR: JAMES ADAMS
NAVAL RESEARCH LABORATORY,
WASHINGTON, DISTRICT OF COLUMBIA

SUMMARY OF OBSERVATIONS

Bay H12 contained a 12"-deep (30.5 cm) experiment tray which accommodated one of two M0001 passive experiments, the other of which was located in Bay H03. The objective of this experiment was to investigate three components of heavy nuclei in space: (1) a recently observed anomalous component of low-energy nuclei of N, O, and Ne, (2) the heavy nuclei in the Van Allen radiation belts, and (3) the ultra-heavy (UH) nuclei (atomic number [Z]>30) of the galactic radiation. The experimental package consisted of eight detector modules (four each in Bays H03 and H12); each module or stack possessed an active area of 12" x 14" (30.5 x 35.6 cm). Individual stacks consisted of two parts, one for low-energy ions and one for cosmic rays. The larger cosmic-ray detectors resided in sealed containers, below the low-energy ion detectors, and consisted of sheets of track-detecting (primarily CR-39) plastic. The low-energy ion detectors consisted of lexan sheets which were secured to the top of the cosmic-ray detectors by aluminum frames, termed "Z-frames". Each stack was shielded from the space environment by a multi-layer insulation blanket composed of alternating layers of 0.25 mil (~25 μm) thick sheets of Dupont Type-A Mylar (aluminized on both sides) and Dupont Dacron netting (70-886-10). The top layer (space-facing) of these blankets, a Dupont Kapton aluminized H-film, was painted white with Chemglaze II. This paint consisted of inorganic pigment grains held within an organic-based binder. The blankets were attached to the Z-frames with a space-qualified tape.

A notable feature of the multi-layer thermal blankets was that they had curled back on orbit, exposing themselves to oxygen erosion. Blanket surfaces which had not curled back were a coffee-brown color, while surfaces which had curled back and were subjected to direct oxygen erosion were a mottled brown and white. Impacts into the brown blankets exhibited spalled regions which were white, suggesting that the impact shock had removed surficial brown material. There were many apparent low-angle impacts into these blankets, as indicated by elongated white spall features. As a result of the blankets curling back, impacts were found on both the top- and backsides of many blankets. Several notable impact features were present on the multi-layer thermal blankets which suggested entry from the rear, undoubtedly occurring after the blanket had curled back. Impacts from the rear produced bulges, and occasional cracks in the blanket layers. Most impacts into the lexan sheets, which became exposed after the thermal blankets had peeled back, were accompanied by radial cracks within the top lexan layer. Several of the impactors penetrated more than one layer of lexan, one up to eight layers. The M0001 thermal blankets should have served as good meteoroid and debris collection cells.

The M&D SIG survey identified a total of 85 impact features on the H12 experiment tray, the multi-layer blankets, and the clamps associated with this tray. Unlike later documentation activities for tray H12 (and H03), all impact features optically discernable on the multi-layer blankets were photodocumented. The photodocumentation of the thermal blankets for H12 and H03 was conducted before the experiment trays were removed from LDEF, as several of the blankets had to be removed to facilitate LDEF rotation and deintegration operations. Features which were photodocumented on the various thermal blankets were assigned different "Component Numbers" (E01 through E05) than those which were photodocumented on the experiment tray (E00; Figure H12-1). Sixty features were identified which were <0.5 mm in diameter (15 on the experiment-tray flanges, 18 on the various clamps associated with this tray, three on other experimental-hardware surfaces [one on a Z-frame], and 24 in other experimental surfaces [lexan and aluminum surfaces]. Twenty two features were photodocumented from the various thermal blankets which were examined prior to deintegration of the experiment tray (18 of which were <0.3 mm in diameter, and four which were between 0.3

mm and 0.5 mm in diameter). One of the remaining three features was located on clamp C10 and measured ~1.3 mm in diameter, one was a penetration through some aluminum foil and subsequent impact into and an aluminum substrate with a crater diameter of ~0.5 mm in diameter, while the third feature was located in an aluminum Z-Frame and measured ~1.0 mm in diameter.

FEATURE SUMMARY

	CLAMPS, BOLTS, & SHIMS	TRAY FLANGES	EXPERIMENTAL SURFACES	TOTALS
<0.3 mm			18	18
>0.3 mm			4	4
<0.5 mm	18	15	27	60
>0.5 mm	1		2	3
TOTALS	19	15	51	85

The largest impact features found on this tray were (1) an ~1.0 mm diameter crater on an aluminum Z-frame, and (2) an ~1.3 mm diameter crater on clamp C10.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The standard M&D SIG pre-deintegration inspection was conducted on February 21, 1990, at which time the experiment-tray cover had already been installed. During this inspection four features on various clamps and one on the outer experiment-tray flange were identified; none were located in areas where they would be damaged during deintegration of the experiment tray. As had been noted during LDEF retrieval operations, the thermal blankets had become partially detached from the Z-frames and were peeling back. These loose blankets had to be removed before the experiment-tray cover could be installed. Accordingly, on February 6, 1990, thermal blankets "E", "F", and "G" were removed from the experiment tray by the experiment's Principal Investigator. Only the bottom half of blanket "H" was removed leaving the top half attached to the experiment tray. Each removed blanket was stapled together along one edge (taking care to not disturb impact features), to permit later registration of particulate penetrations through multiple-blanket layers. In places where the thermal blanket had peeled back on orbit, impact features were apparent in the lexan detector stacks, some of which were accompanied by large cracks. No impacts were noted in the portions of the lexan detectors which were still shielded by the multi-layer blankets.

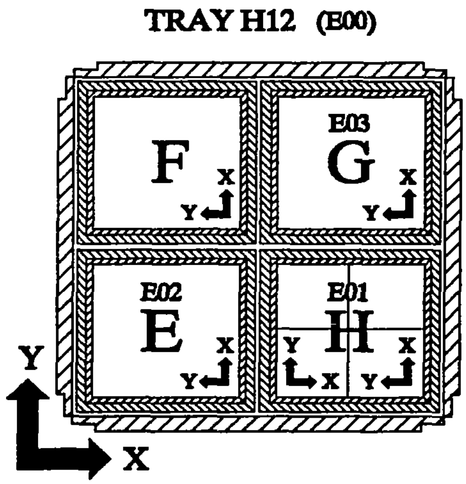


Figure H12-1. Diagram illustrating the orientation of the experiment tray and *multi-layer thermal blankets during M&D SIG photodocumentation.*

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.125" (30.5 mm) thick, chromic-anodized 6061-T6 experiment-tray flanges.

DOCUMENTATION:

Examination and photodocumentation of the H12 experiment tray, and the still attached top half of blanket "H", was conducted on March 15, 1990 in the vertical position utilizing M&D SIG System #2. Blankets "E", "G", and the half of "H", which had been previously removed from the experiment tray, were documented utilizing M&D SIG System #1 on February 6 through 12, 1990. Blanket "F" was examined on February 7, 1990, while the bolts, clamps, and shims associated with this tray were examined on March 15, 1990, all utilizing M&D SIG System #3. The coordinates for all features were measured with a metric tape measure or scale. Note that the various multi-layer thermal blankets were photodocumented in an orientation which was rotated 90° counter-clockwise to that of the experiment tray and the remaining half of blanket "H" Figure H12-1).

Bolt-Hole Registration - Not Determined

Impact Features Imaged on Experiment-Tray Clamps, Bolts, and Shims

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LC100001.H12	RC100001.H12	26	47		1.3	Al	

Impact Features Imaged on Exposed Experimental Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.H12	RE000001.H12	542	520		0.3 x 0.7	Lexan	
LE000002.H12	RE000002.H12	673	250		0.4	Lexan	
LE000003.H12	RE000003.H12	717	250		0.3	Lexan	
LE000004.H12	RE000004.H12	347	630		0.4	Lexan	*13*
LE000005.H12	RE000005.H12	350	740		0.2 x 0.3	Lexan	
LE000006.H12	RE000006.H12	147	37		0.5	Al (Foil)	*1*
LE000007.H12	RE000007.H12	173	840		1.0	Al (Z-Frame)	
LE010001.H12	RE010001.H12	31	84		0.2 x 0.3	MTB	*z*
LE020001.H12	RE020001.H12	25	60		0.2	MTB	*z*
LE020002.H12	RE020002.H12	60	147		0.4	MTB	*z*
LE020003.H12	RE020003.H12	8	171		0.3	MTB	*z*
LE020004.H12	RE020004.H12	19	184		0.2 x 0.4	MTB	*z*
LE020005.H12	RE020005.H12	105	291		0.3 x 0.4	MTB	*z*
LE020006.H12	RE020006.H12	129	247		0.1 x 0.2	MTB	*z*
AE020006.H12	BE020006.H12	129	247		0.1 x 0.2	MTB	*z*
LE020007.H12	RE020007.H12	135	265		0.2	MTB	*z*
LE020008.H12	RE020008.H12	135	102		0.1	MTB	*z*
LE020009.H12	RE020009.H12	242	65		0.2 x 0.4	MTB	*d,z*
LE020010.H12	RE020010.H12	285	62		ND	MTB	*2,d,z*
AE020010.H12	BE020010.H12	285	62		ND	MTB	*2,d,z*
LE020011.H12	RE020011.H12	268	118		0.1 x 0.2	MTB	*z*
LE020012.H12	RE020012.H12	210	225		0.1	MTB	*z*
LE020013.H12	RE020013.H12	216	133		0.1 x 0.2	MTB	*z*
LE020014.H12	RE020014.H12	138	260		0.1	MTB	*z*
LE030001.H12	RE030001.H12	108	15		0.2	MTB	*z*
LE030002.H12	RE030002.H12	133	6		0.4	MTB	*z*
LE030003.H12	RE030003.H12	17	39		0.2	MTB	*z*
LE030004.H12	RE030004.H12	235	28		0.3	MTB	*z*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE030005.H12	RE030005.H12	292	25		0.3	MTB	*z*
AE030005.H12	BE030005.H12	292	25		0.3	MTB	*13,z*
LE030006.H12	RE030006.H12	301	7		0.3	MTB	*z*
LE030007.H12	RE030007.H12	352	57		0.2	MTB	*z*
LE030008.H12	RE030008.H12	8	67		0.1 x 0.2	MTB	*z*
LE030009.H12	RE030009.H12	22	85		0.2	MTB	*z*
AE030009.H12	BE030009.H12	22	85		0.2	MTB	*z*
LE030010.H12	RE030010.H12	335	140		0.2	MTB	*z*
LE030011.H12	RE030011.H12	310	153		0.4	MTB	*3,z*
LE030012.H12	RE030012.H12	289	192		0.1 x 0.2	MTB	*z*
LE030013.H12	RE030013.H12	296	111		0.1 x 0.2	MTB	*z*
LE030014.H12	RE030014.H12	350	228		0.2	MTB	*z*
LE030015.H12	RE030015.H12	359	237		0.1	MTB	*z*
LE030016.H12	RE030016.H12	335	265		0.1	MTB	*z*
AE030016.H12	BE030016.H12	335	265		0.1	MTB	*z*
LE030017.H12	RE030017.H12	345	285		0.3	MTB	*z*
LE030018.H12	RE030018.H12	319	327		0.2	MTB	*z*
LE030019.H12	RE030019.H12	188	290		0.3	MTB	*z*
AE030019.H12	BE030019.H12	188	290		0.3	MTB	*k,z*
LE030020.H12	RE030020.H12	187	275		0.1	MTB	*z*
LE030021.H12	RE030021.H12	31	305		0.1	MTB	*z*
LE030022.H12	RE030022.H12	35	315		0.1	MTB	*z*
LE050001.H12	RE050001.H12	254	293		0.1	MTB	*d,z*
LE050002.H12	RE050002.H12	352	272		0.3	MTB	*9,d,z*
LE050003.H12	RE050003.H12	346	283		0.3	MTB	*4,z*
AE050003.H12	BE050003.H12	346	283		0.3	MTB	*4,z*
LE050004.H12	RE050004.H12	23	238		0.1	MTB	*5,z*
LE050005.H12	RE050005.H12	52	247		0.1	MTB	*6,z*
LE050006.H12	RE050006.H12	54	215		ND	MTB	*7,z*
LE050007.H12	RE050007.H12	9	214		0.1	MTB	*4,z*
LE050008.H12	RE050008.H12	74	210		0.1	MTB	*8,z*
LE050009.H12	RE050009.H12	327	201		0.1	MTB	*5,13,z*
LE050010.H12	RE050010.H12	325	206		0.1	MTB	*13,z*
LE050011.H12	RE050011.H12	73	197		ND	MTB	*10,z*
LE050012.H12	RE050012.H12	132	166		0.1	MTB	*z*
LE050013.H12	RE050013.H12	87	116		0.2	MTB	*11,z*
LE050014.H12	RE050014.H12	205	94		0.3	MTB	*12,z*
AE050014.H12	BE050014.H12	205	94		0.3	MTB	*12,z*
LE050015.H12	RE050015.H12	132	71		0.1	MTB	*5,z*
LE050016.H12	RE050016.H12	215	63		0.1	MTB	*z*
LE050017.H12	RE050017.H12	257	58		0.2	MTB	*12,13,z*
LE050018.H12	RE050018.H12	67	67		0.1	MTB	*12,13,z*
LE050019.H12	RE050019.H12	64	69		0.1	MTB	*z*
LE050020.H12	RE050020.H12	132	38		0.2	MTB	*z*
LE050021.H12	RE050021.H12	251	14		0.2	MTB	*z*
LE050022.H12	RE050022.H12	134	19		0.1	MTB	*12,z*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

MTB - Multi-layer thermal blanket

ND - Not Determined

1 - Impact into aluminum foil originally at the edge of a thermal blanket.
2 - No impact crater apparent.
3 - Interesting paint peeling.
4 - Diameter given is for penetration hole, associated spall zone measures ~0.5 mm.
5 - Diameter given is for penetration hole, associated spall zone measures ~0.2 mm.
6 - Diameter given is for penetration hole, associated spall zone measures ~0.1 mm.
7 - No penetration, probable low-angle impact, associated spall zone measures ~0.5 mm.
8 - Probable low-angle impact, associated spall zone measures ~0.1 x 0.3 mm.
9 - Incorrect Y-coordinate (Y = 292) input into image file.
10 - Possible impact from rear, no penetration.
11 - Diameter given is for penetration hole, associated spall zone measures ~0.3 mm.
12 - An impact from the rear of the blanket.
13 - Large cracks in target material associated with feature.

OTHER PHOTODOCUMENTATION:

Pre-Flight - 108-KSC-384C-331/6
On-Orbit - S32-75-67, S32-85-06
Pre-Deintegration - KSC-390C-828.05 through KSC-390C-828.08, KSC-390C-828.12, KSC-390C-829.01 through KSC-390C-829.03, KSC-390C-1030.04, KSC-390C-1011.07, KSC-390C-1011.08, KSC-390C-1013.01
Post Deintegration - KSC-390C-833.02, KSC-390C-1012.02 through KSC-390C-1012.05, KSC-390C-1997.07
M&D SIG Photos - S90-43376, S90-43388 through S90-43390

ARCHIVED MATERIALS:

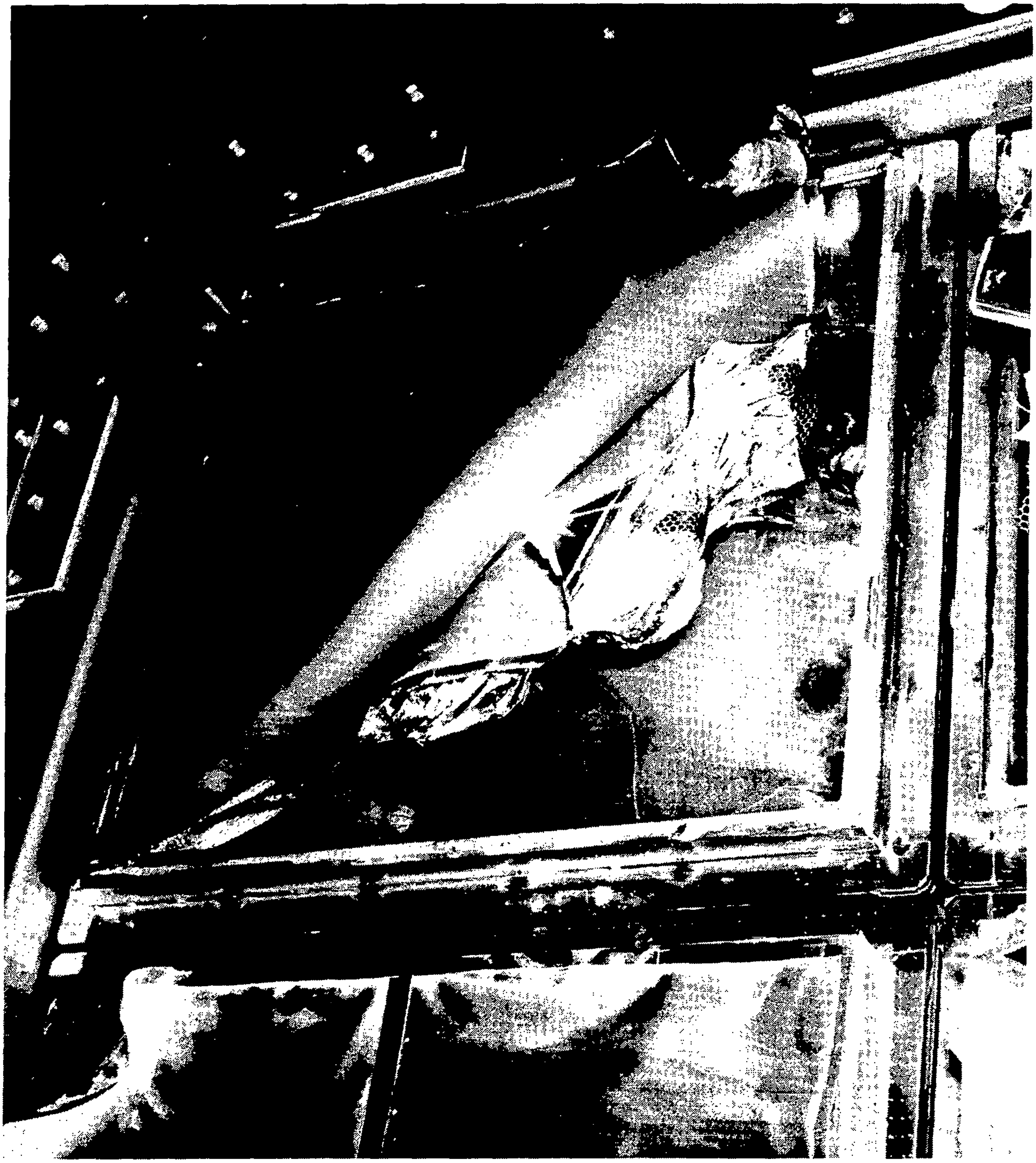
Clamps - H12C02, H12C04, H12C09, H12C10, H12C11, and H12C12
Other - H12E00A - Top lexan detector sheet (Detector "G")
H12E02- Multi-layer thermal blanket (Module "E")
H12E03- Multi-layer thermal blanket (Module "G")
H12E05- Multi-layer thermal blanket (Module "F")
LD-21 - Feature H12E00,8 on aluminum foil over a screw
LD-102 through LD-112 - Feature H12E00,1 (12 lexan layers)

NOTE - The cores listed above (LD-102 through LD-112) indicates 12 layers for this feature, but the JSC database only lists 11; there is no listing within the JSC database for the core from layer 1 for this feature.

ACCOMPANYING FIGURES:

Figure H12-2. This pre-deintegration view shows one module of tray H12 with the thermal blanket partially peeled back exposing the lexan detector stack below.

Figure H12-3. This is a view of a penetration hole through one of the H12 multi-layer thermal blankets. The streak adjacent to the hole may be indicative of an oblique impact. View measures ~2 cm across.



3.C. MISCELLANEOUS LDEF HARDWARE

LDEF LOCATION: G13
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W.M. BERRIOS

434 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel G13 was one of four approximately rectangular-shaped thermal panels adjacent to Rows 3, 6, 9, and 12, respectively (Earth-facing component measuring ~24" x 39" [61 x 99.5 cm], while the Row 12-facing strip measured ~6.25" x 39" [15.9 x 99.5]). The total exposed surface area of the rectangular-shaped thermal panels was ~1,180 in^2 (~7,673 cm^2), approximately 936 in^2 (~6,091 cm^2) of which was in the Earth-facing direction and ~244 in^2 (~1,582 cm^2) of which was in the Row 12-facing direction. Panel G13 was attached to the spacecraft by nineteen 303 stainless steel bolts (twelve on the Earth-facing side and seven on the Row 12-facing strip). An ~3" in diameter amber reflector was attached to a 0.062" (1.6 mm) thick, chromic-anodized aluminum plate which in turn, was attached to the thermal panel at bolt locations G13S01D and G13S01E on the Row 12-facing strip.

Detailed examination of Thermal Panel G13 revealed 119 features, 107 of which were <0.5 mm in diameter and were not photodocumented (21 on the earth-facing component, 79 on the Row 12-facing strip, three on bolts (G13S01K, G13S01L, and G13S02O), and four on the green reflector). Of the 12 remaining impacts six resided on the earth-facing component, two of which were <0.5 mm in diameter, and one which was 0.9 mm in diameter which was the largest impact on the earth-facing component. Of the six imaged impacts residing on the Row 12-facing strip, one was <0.5 mm in diameter, and the remaining four ranged in diameter from 0.4 mm to 0.7 mm, the largest being a circular impact 0.7 mm in diameter. Of the 12 features photo documented five were highly oblique impacts (three on the Earth-facing component and one on the Row 12-facing strip), and appeared as nothing more than streaks or scratches until examined under the microscope. Such highly-oblique features were not uncommon on the various Earth-end thermal panels and, in general, possessed semi-minor axes of <0.5 mm, while the semi-major axes were commonly measured at >1.0 mm in length.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 12-FACING STRIP	EARTH-FACING COMPONENT	TOTALS
<0.5 mm	7	81	26	114
>0.5 mm		4	1	5
TOTALS	7	85	27	119

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel G13 was conducted on March 29, 1990 and revealed no features on the panel's surface near the bolts, or on the bolts themselves that could be damaged as a result of removing the panel from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel G13 was conducted on April 16, 1990. The Earth-facing component was photodocumented in the horizontal position using M&D SIG System # 2 and the Row 12-facing strip was photodocumented in the vertical position using M&D SIG System #3. The coordinates were documented using Coordinate Registration System #3. The bolts and reflector associated with this thermal panel were scanned with M&D SIG System #1. As a result of the standard adopted by the M&D SIG A-Team for the assignment of the (0,0) reference point for all hardware removed from the LDEF spacecraft (see Section 2.C.6.a), Earth-end thermal panels received (0,0) reference points that often lead to negative X- or Y- coordinate values for some features (Figure G13-1). In addition, all features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the Earth-facing component to the location of the feature on the row-facing strip.

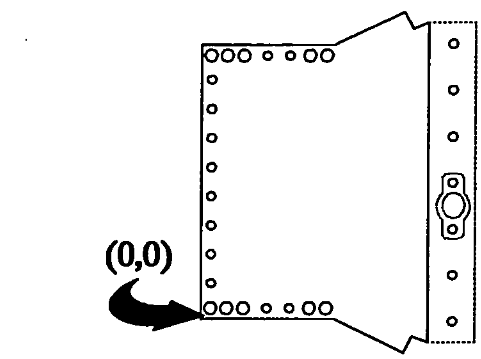


Figure G13-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel G13.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.G13	RE000001.G13	630	57	82	0.7	Al	*1,3*
LE000002.G13	RE000002.G13	630	98	98	0.6	Al	*1,3*
LE000003.G13	RE000003.G13	630	243	75	0.2 x 0.1	Al	*1,3,5*
LE000004.G13	RE000004.G13	630	116	105	0.5	Al	*1*
AE000004.G13	BE000004.G13	630	116	105	0.5	Al	*1,4*
LE000005.G13	RE000005.G13	630	166	88	ND	Al	*1,5*
LE000006.G13	RE000006.G13	630	579	68	0.5	Al	*1*
AE000006.G13	BE000006.G13	579	68	68	0.5	Al	*1,4*
LE000007.G13	RE000007.G13	611	892		ND	Al	*2,w*
LE000008.G13	RE000008.G13	475	883		ND	Al	*2,w*
LE000009.G13	RE000009.G13	486	592		ND	Al	*2,w*
LE000010.G13	RE000010.G13	568	498		0.2	Al	*2,w*
LE000011.G13	RE000011.G13	140	715		0.2	Al	*2*
LE000012.G13	RE000012.G13	146	307		0.9	Al	*2*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Feature located on Row 12-facing strip of thermal panel.
2 - Feature located Earth-facing component of thermal panel.
3 - Image taken at 90° out of phase in the Z direction.
4 - Reason for taking a second photo not documented.
5 - Highly oblique impact feature.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-deintegration
Post Deintegration - KSC-390C-3417.09, KSC-390C-3511.04, and KSC-390C-3511.05
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - G13S01K, G13S01L, and G13S02O

LDEF LOCATION: G14
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W.M. BERRIOS

434 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel G14 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (Earth-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 1-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the Earth-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 1-facing direction. Panel G14 was attached to the spacecraft by eighteen 303 stainless steel bolts (nine on the Earth-facing side and nine on the Row 1-facing strip).

Detailed examination of Thermal Panel G14 revealed 37 features, 30 of which were <0.5 mm in diameter and were not photodocumented (14 on the earth-facing component, 15 on the Row 1-facing strip, and one on the thermal panel bolt G14S01O). Of the ten remaining impacts five resided on the earth-facing component, one of which was <0.5 mm in diameter, and one which was ~1.4 mm in diameter which was the largest impact on the earth-facing component. Of the two imaged impacts residing on the Row 1-facing strip, both were >0.5 mm, the largest one being ~0.6 mm in diameter. Of the seven features photo documented three were highly oblique impacts, all residing on the Earth-facing component, and appeared as nothing more than streaks or scratches until examined under the microscope. Such highly-oblique features were not uncommon on the various Earth-end thermal panels and, in general, possessed semi-minor axes of <0.5 mm, while the semi-major axes were commonly measured at >1.0 mm in length.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 1-FACING STRIP	EARTH-FACING COMPONENT	TOTALS
<0.5 mm	1	15	18	34
>0.5 mm		2	1	3
TOTALS	1	17	19	37

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel G14 was conducted on March 29, 1990 and revealed no features on the panel's surface near the bolts, or on the bolts themselves that could be damaged as a result of removing the panel from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel G14 was conducted on April 23, 1990. Both the Earth-facing component and the Row 1-facing strip were photodocumented (in the horizontal and vertical mode, respectively) using M&D SIG System #2 and the coordinates were documented using Coordinate Registration System #3. The bolts associated with this thermal panel were scanned with M&D SIG System #1. As a result of the standard adopted by the M&D SIG A-Team for the assignment of the (0,0) reference point for all hardware removed from the LDEF spacecraft (see Section 2.C.6.a), Earth-end thermal panels received (0,0) reference points that often lead to negative X- or Y- coordinate values for some features (Figure G14-1). In addition, all features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the Earth-facing component to the location of the feature on the row-facing strip.

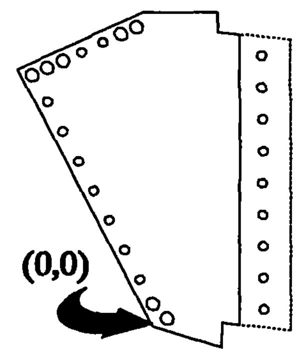


Figure G14-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel G14.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.G14	RE000001.G14	111	43	47	0.6	Al	*1*
LE000002.G14	RE000002.G14	111	713	80	0.5	Al	*1*
LE000003.G14	RE000003.G14	47	864		ND	Al	*2,3,4,*
LE000004.G14	RE000004.G14	65	654		1.4	Al	*2,4,k*
LE000005.G14	RE000005.G14	40	850		ND	Al	*2,4*
LE000006.G14	RE000006.G14	270	850		0.1	Al	*2*
LE000007.G14	RE000007.G14	-30	430		ND	Al	*2,4*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Feature located on Row 1-facing strip of thermal panel.
2 - Feature located Earth-facing component of thermal panel.
3 - Image rotated -35°.
4 - Highly oblique feature.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-deintegration
Post Deintegration KSC-390C-3501.10 and KSC-390C-3509.11
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - G14S01O

LDEF LOCATION: G15
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W.M. BERRIOS

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SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel G15 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (Earth-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 2-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the Earth-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 2-facing direction. Panel G15 was attached to the spacecraft by eighteen 303 stainless steel bolts (nine on the Earth-facing side and nine on the Row 2-facing strip). An ~3" in diameter green reflector was attached to a 0.062" (1.6 mm) thick, chromic-anodized aluminum plate which in turn, was attached to the thermal panel at bolt locations G15S01D and G15S01E on the Row 2-facing strip.

Detailed examination of Thermal Panel G15 revealed 28 features, 23 of which were <0.5 mm in diameter and were not photodocumented (four on the earth-facing component, 16 on the Row 2-facing strip, one on the thermal panel bolt G15S01E, and two on the green reflector). Of the five remaining impacts one resided on the earth-facing component which was an oblique impact ~0.8 x 0.5 mm in diameter. The one imaged impact residing on the Row 2-facing strip, was an oblique impact ~0.5 x 0.4 mm in diameter. Of the five features photo documented three were highly oblique impacts, (two on the Earth-facing component and one on the Row 2-facing strip), and appeared as nothing more than streaks or scratches until examined under the microscope. Such highly-oblique features were not uncommon on the various Earth-end thermal panels and, in general, possessed semi-minor axes of <0.5 mm, while the semi-major axes were commonly measured at >1.0 mm in length.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 2-FACING STRIP	EARTH-FACING COMPONENT	TOTALS
<0.5 mm	3	18	6	27
>0.5 mm			1	1
TOTALS	3	18	7	28

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel G15 was conducted on March 29, 1990 and revealed no features on the panel's surface near the bolts, or on the bolts themselves that could be damaged as a result of removing the panel from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel G15 was conducted on April 23, 1990. Both the Earth-facing component and the Row 2-facing strip were photodocumented (in the horizontal and vertical mode, respectively) using M&D SIG System #2 and the coordinates were documented using Coordinate Registration System #3. The bolts and reflector associated with this thermal panel were scanned with M&D SIG System #1. As a result of the standard adopted by the M&D SIG A-Team for the assignment of the (0,0) reference point for all hardware removed from the LDEF spacecraft (see Section 2.C.6.a), Earth-end thermal panels received (0,0) reference points that often lead to negative X- or Y- coordinate values for some features (Figure G15-1). In addition, all features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the Earth-facing component to the location of the feature on the row-facing strip.

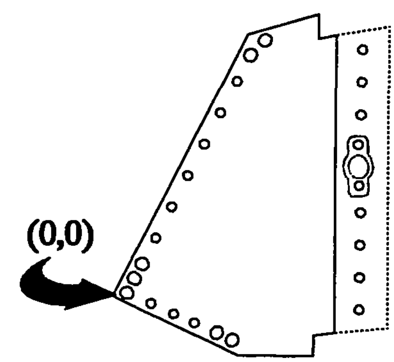

Figure G15-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel G15.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.G15	RE000001.G15	306	368		ND	Al	*1,3*
LE000002.G15	RE000002.G15	538	748		0.8 x 0.5	Al	*1*
LE000003.G15	RE000003.G15	413	272		ND	Al	*1,3*
LE000004.G15	RE000004.G15	569	49	124	ND	Al	*2,3,4*
AE000004.G15	BE000004.G15	569	49	124	ND	Al	*2,3,5*
LE000005.G15	RE000005.G15	569	250	15	0.5 x 0.4	Al	*3,d*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Feature located Earth-facing component of thermal panel.
2 - Feature located on Row 2-facing strip of thermal panel.

3 - Highly oblique feature.
4 - Length of oblique impact ~2.0 cm.
5 - Not documented why second image was taken.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-deintegration
Post Deintegration - KSC-390C-3417.08, KSC-390C-3510.10, and KSC-390C-3510.12
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - G15S01E

LDEF LOCATION: G16
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W.M. BERRIOS

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SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel G16 was one of four approximately rectangular-shaped thermal panels adjacent to Rows 3, 6, 9, and 12, respectively (Earth-facing component measuring ~24" x 39" [61 x 99.5 cm], while the Row 3-facing strip measured ~6.25" x 39" [15.9 x 99.5]). The total exposed surface area of the rectangular-shaped thermal panels was ~1,180 in^2 (~7,673 cm^2), approximately 936 in^2 (~6,091 cm^2) of which was in the Earth-facing direction and ~244 in^2 (~1,582 cm^2) of which was in the Row 3-facing direction. Panel G16 was attached to the spacecraft by nineteen 303 stainless steel bolts (ten on the Earth-facing side and nine on the Row 3-facing strip). An ~3" in diameter green reflector was attached to a 0.062" (1.6 mm) thick, chromic-anodized aluminum plate which in turn, was attached to the thermal panel at bolt locations G16S01N and G16S01O on the Earth-facing component.

Detailed examination of Thermal Panel G16 located only 15 features, all of which resided on the Earth-facing component and were <0.5 mm in diameter. Only one of these features (~0.3 mm in diameter) was photodocumented due to the assocaition of some debris with the feature. Morphologically, the craters examined on this thermal panel were typical of craters produced in similar material under controlled, laboratory conditions.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 3-FACING STRIP	EARTH-FACING COMPONENT	TOTALS
<0.5 mm			15	15
>0.5 mm				
TOTALS			15	15

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel G16 was conducted on March 29, 1990 and revealed no features on the panel's surface near the bolts, or on the bolts themselves that could be damaged as a result of removing the panel from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel G16 was conducted on April 23, 1990. The Earth-facing end of the panel was examined and photodocumented in the horizontal position, while the Row 3-facing strip was examined and photodocumented in the vertical mode. The one imaged feature was photodocumented utilizing M&D SIG System #1 and Coordinate Registration System #3. The bolts and reflector associated with this thermal panel were scanned with M&D SIG System #1. As a result of the standard adopted by the M&D SIG A-Team for the assignment of the (0,0) reference point for all hardware removed from the LDEF spacecraft (see Section 2.C.6.a), Earth-end thermal panels received (0,0) reference points that often lead to neagative X- or Y-coordinate values for some features (Figure G16-1).

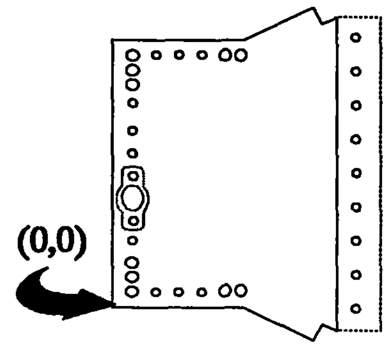

Figure G16-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel G16.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.G16	RE000001.G16	366	461		0.3	Al	*d*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration - KSC-390C-3417.07, KSC-390C-3509.07, and KSC-390C-3509.08
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION: G17
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W.M. BERRIOS
434 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel G17 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (Earth-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 4-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the Earth-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 4-facing direction. Panel G17 was attached to the spacecraft by nineteen 303 stainless steel bolts (ten on the Earth-facing side and nine on the Row 4-facing strip). An ~3" in diameter green reflector was attached to a 0.062" (1.6 mm) thick, chromic-anodized aluminum plate which in turn, was attached to the thermal panel at bolt locations G17S01D and G17S01E on the Row 4-facing strip.

Detailed examination of Thermal Panel G17 located 27 features, 21 of which were <0.5 mm in diameter and were not photodocumented (17 on the Earth-facing component and four on the Row 4-facing strip, including one feature on the anodized aluminum plate behind the reflector). Two of the remaining six features were photodocumented on the Row 4-facing strip measuring ~0.7 and ~1.1 mm in diameter, the latter of which was the largest feature found on panel G17; these features were typical of laboratory-produced hypervelocity impact craters in aluminum. Of the four features photodocumented on the Earth-facing component of panel G17, three were highly oblique and appeared as nothing more than streaks or scratches until examined under the microscope. Such highly-obliques features were not uncommon on the various Earth-end thermal panels and, in general, possessed semi-minor axes of <0.5 mm, while the semi-major axes were commonly measured at >1.0 mm in length.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 4-FACING STRIP	EARTH-FACING COMPONENT	TOTALS
<0.5 mm		4	17	21
>0.5 mm		2	4	6
TOTALS		6	21	27

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel G17 was conducted on March 29, 1990 and revealed no features on the panel's surface near the bolts, or on the bolts themselves that could be damaged as a result of removing the panel from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel G17 was conducted on April 23, 1990. Both the Earth-facing component and the Row 4-facing strip were photodocumented (in the horizontal and vertical mode, respectively) with M&D SIG System #1 and Coordinate Registration System #3. The bolts and reflector associated with this thermal panel were scanned with M&D SIG System #1. As a result of the standard adopted by the M&D SIG A-Team for the assignment of the (0,0) reference point for all hardware removed from the LDEF spacecraft (see Section 2.C.6.a), Earth-end thermal panels received (0,0) reference points that often lead to neagative X- or Y-coordinate values for some features (Figure G17-1). In addition, all features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the Earth-facing component to the location of the feature on the row-facing strip.

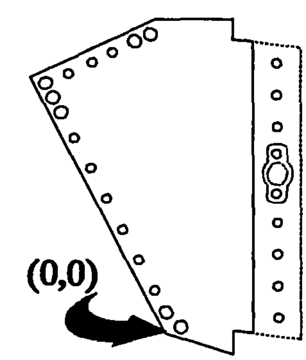

Figure G17-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel G17.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.G17	RE000001.G17	-84	223		ND	Al	*1,2*
LE000002.G17	RE000002.G17	-73	550		ND	Al	*1,2*
LE000003.G17	RE000003.G17	-22	703		0.3 x 0.5	Al	*2*
LE000004.G17	RE000004.G17	54	481		ND	Al	*1,2*
LE000005.G17	RE000005.G17	111	234	185	1.1	Al	*3*
LE000006.G17	RE000006.G17	111	852	84	0.5	Al	*3*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Feature located on Earth-facing component of thermal panel.
2 - Highly-oblique feature.

3 - Feature located on Row 4-facing strip of thermal panel.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration - KSC-390C-3417.06, KSC-390C-3510.04, and KSC-390C-3510.05
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION: G18
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W.M. BERRIOS

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SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel G18 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (Earth-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 5-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the Earth-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 5-facing direction. Panel G18 was attached to the spacecraft by eighteen 303 stainless steel bolts (nine on the Earth-facing side and nine on the Row 5-facing strip).

Detailed examination of Thermal Panel G18 revealed 27 features, 23 of which were <0.5 mm in diameter and were not photodocumented (ten on the Earth-facing component and 13 on the Row 5-facing strip). Only one (highly oblique) of the remaining four features were photodocumented on the Row 5-facing strip, while the other three were located on the Earth-facing component. Of these latter three features, one was highly oblique in nature and two exhibited fairly circular shapes; the largest of these features measured ~0.4 x 0.5 mm. These highly oblique features generally appeared as little more than streaks or scratches until examined under the microscope. Such features were not uncommon on the various Earth-end thermal panels and, in general, possessed semi-minor axes of <0.5 mm, while the semi-major axes were commonly measured at >1.0 mm in length. Morphologically, the non-oblique craters examined on this thermal panel were typical of craters produced in similar material under controlled, labortory conditions.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 5-FACING STRIP	EARTH-FACING COMPONENT	TOTALS
<0.5 mm		13	10	23
>0.5 mm		1	3	4
TOTALS		14	13	27

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel G18 was conducted on March 29, 1990 and revealed no features on the panel's surface near the bolts, or on the bolts themselves that could be damaged as a result of removing the panel from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel G18 was conducted on April 23, 1990. Both the Earth-facing component and the Row 5-facing strip were photodocumented (in the horizontal and vertical mode, respectively) with M&D SIG System #2 and Coordinate Registration System #3. The bolts associated with this thermal panel were scanned with M&D SIG System #1. As a result of the standard adopted by the M&D SIG A-Team for the assignment of the (0,0) reference point for all hardware removed from the LDEF spacecraft (see Section 2.C.6.a), Earth-end thermal panels received (0,0) reference points that often lead to neagative X- or Y-coordinate values for some features (Figure G14-1). In addition, all features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the Earth-facing component to the location of the feature on the row-facing strip.

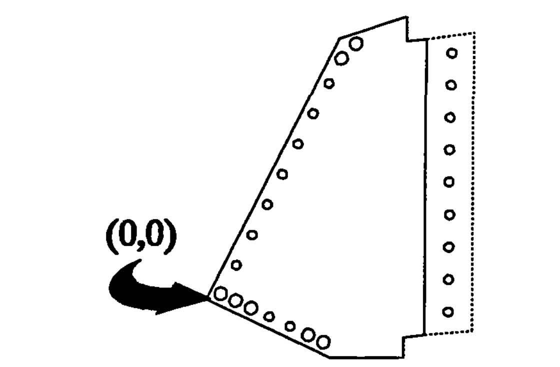

Figure G18-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel G18.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.G18	RE000001.G18	570	408		ND	Al	*1*
LE000002.G18	RE000002.G18	567	367		0.4 x 0.5	Al	*2,d*
LE000003.G18	RE000003.G18	300	155		0.2	Al	*2*
LE000004.G18	RE000004.G18	421	401		ND	Al	*2,3*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Feature located on Row 5-facing strip of thermal panel.
2 - Feature located on Earth-facing component of thermal panel.
3 - Highly-oblique feature.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration - KSC-390C-3510.07 and KSC-390C-3510.08
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION: G19
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W.M. BERRIOS
434 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel G19 was one of four approximately rectangular-shaped thermal panels adjacent to Rows 3, 6, 9, and 12, respectively (Earth-facing component measuring ~24" x 39" [61 x 99.5 cm], while the Row 6-facing strip measured ~6.25" x 39" [15.9 x 99.5]). The total exposed surface area of the rectangular-shaped thermal panels was ~1,180 in^2 (~7,673 cm^2), approximately 936 in^2 (~6,091 cm^2) of which was in the Earth-facing direction and ~244 in^2 (~1,582 cm^2) of which was in the Row 6-facing direction. Panel G19 was attached to the spacecraft by nineteen 303 stainless steel bolts (ten on the Earth-facing side and nine on the Row 6-facing strip). An ~3" in diameter amber reflector was attached to a 0.062" (1.6 mm) thick, chromic-anodized aluminum plate which in turn, was attached to the thermal panel at bolt locations G19S01D and G19S01E on the Row 6-facing strip.

Thermal panel G19 was one of the first pieces of hardware to be removed from LDEF and examined by the M&D SIG. Several features were imaged multiple times at different magnifications and under different lighting conditions in an attempt to optimize procedures. There are also several instances where features were imaged with more than one system under identical conditions and assigned the same image numbers. Feature diameters that were <1 mm were not recorded during documentation of this panel; the criterion for feature diameter measurement on solid surfaces was lowered to 0.5 mm after inspection of this first piece of LDEF hardware.

There were a total of 13 features identified on all G19 surfaces. Seven of these features, including one feature on the reflector's aluminum baseplate, were on the Row 6 face strip and were all <1 mm in diameter. Of the remaining five features, all located on the Earth-facing component of the thermal panel, three were highly oblique and had lengths >1mm. The largest of these was feature LE000012.G19 and was ~0.3 x 1.4 mm in size. A second oblique feature measuring ~0.2 x 1.0 mm had an apparent debris pattern surrounding it that measured ~0.3 x 3.4 mm. The third oblique feature was ~0.1 x 1.3 mm in size. Other than these oblique features, the morphology of the remaining craters examined on this thermal control panel was typical of craters formed in similar material under controlled, laboratory conditions.

A possible piece of impactor residue was noted in feature LE000002.G19, located on the Earth-facing component of the thermal panel. A higher magnification view of this feature shows the possible residue (AE000002.G19).

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 9-FACING STRIP	EARTH-FACING COMPONENT	TOTALS
<1.0 mm	1	7	3	11
>1.0 mm			2	2
TOTALS	1	7	5	13

M&D SIG INSPECTIONS

PRE-DEINTEGRATION:

No features were found on the bolts during the initial inspection of Thermal Panel G19, before it was removed from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel G19 was conducted on February 5 and 7, 1990. The Earth-facing end of the panel was examined and photodocumented in the horizontal position, while the Row 9 facing strip was examined and photodocumented in the vertical mode. Imaged feature were photodocumented utilizing M&D SIG System #1 and Coordinate Registration System #3. The (0,0) reference point for this panel is unlike any others assigned to Earth-end thermal panels (Figure G19-1). Features residing on the Row 6 facing strip were assigned negative Y coordinates; features in similar locations on all thermal panels other than this one and H19 were assigned positive Z values. The panel bolts and reflector were inspected on February 5, 1990 and the one feature found on the reflector was documented with all three systems.

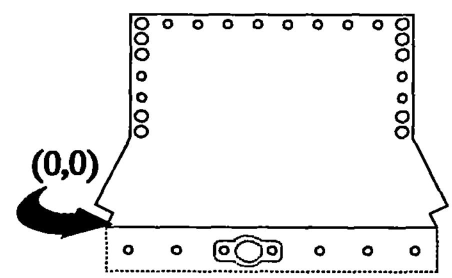

Figure G19-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel G19.

Impact Features Imaged on Thermal Panel Bolts and Reflector

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LF010001.G19	RF010001.G19	22	47		0.3	Al	*1*
AF010001.G19	BF010001.G19	22	47		0.3	Al	*1*

Impact Features Imaged on Thermal Panel Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.G19	RE000001.G19	23	586		ND	Al	
LE000002.G19	RE000002.G19	540	538		ND	Al	*3,d,k*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
AE000002.G19	BE000002.G19	540	538		ND	Al	*2,d,k*
LE000003.G19	RE000003.G19	261	-39		ND	Al	
LE000004.G19	RE000004.G19	362	-74		ND	Al	
LE000005.G19	RE000005.G19	790	-131		ND	Al	
LE000006.G19	RE000006.G19	851	-72		ND	Al	*b*
LE000007.G19	RE000007.G19	877	-43		ND	Al	
LE000008.G19	RE000008.G19	924	-103		ND	Al	
LE000009.G19	RE000009.G19	447	-2		ND	Al	*1*
LE000010.G19	RE000010.G19	940	349		0.2 x 1.0	Al	*1,3,d*
AE000010.G19	BE000010.G19	940	349		0.2 x 1.0	Al	*1,2,d*
LE000011.G19	RE000011.G19	828	331		0.1 x 1.3	Al	*1*
AE000011.G19	BE000011.G19	828	331		0.1 x 1.3	Al	*1,2*
LE000012.G19	RE000012.G19	976	142		0.3 x 1.4	Al	*1*
AE000012.G19	BE000012.G19	976	142		0.3 x 1.4	Al	*1,2*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Multiple image files with this number exist.
2 - Higher magnification view.
3 - Low magnification view of debris surrounding feature.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration - KSC-390C-3417.10 (Reflector Only)
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION: G20
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W.M. BERRIOS
434 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel G20 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (Earth-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 7-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the Earth-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 7-facing direction. Panel G20 was attached to the spacecraft by eighteen 303 stainless steel bolts (nine on the Earth-facing side and nine on the Row 7-facing strip).

Detailed examination of Thermal Panel G20 revealed 120 features, 113 of which were <0.5 mm in diameter and were not photodocumented (nine on the earth-facing component, 103 on the Row 7-facing strip, and one on the thermal panel bolt G20S01F). Of the seven remaining impacts one resided on the earth-facing component which was an oblique impact ~0.6 x 0.8 mm in diameter. Five circular impact features resided on the Row 7-facing strip ranging in diameter from 0.6 mm to 1.9 mm with the later being the largest impact on the thermal panel. Of the seven features photo documented one was a highly oblique impact, located on the Earth-facing component, and appeared as nothing more than streaks or scratches until examined under the microscope. Such highly-oblique features were not uncommon on the various Earth-end thermal panels and, in general, possessed semi-minor axes of <0.5 mm, while the semi-major axes were commonly measured at >1.0 mm in length.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 7-FACING STRIP	EARTH-FACING COMPONENT	TOTALS
<0.5 mm	1	103	10	114
>0.5 mm		5	1	6
TOTALS	1	108	11	120

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel G20 was conducted on March 29, 1990 and revealed no features on the panel's surface near the bolts, or on the bolts themselves that could be damaged as a result of removing the panel from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel G20 was conducted on April 16, 1990. Both the Earth-facing component and the Row 7-facing strip were photodocumented (in the horizontal and vertical mode, respectively) using M&D SIG System #2 and the coordinates were documented using Coordinate Registration System #3. The bolts and reflector associated with this thermal panel were scanned with M&D SIG System #1. As a result of the standard adopted by the M&D SIG A-Team for the assignment of the (0,0) reference point for all hardware removed from the LDEF spacecraft (see Section 2.C.6.a), Earth-end thermal panels received (0,0) reference points that often lead to negative X- or Y- coordinate values for some features (Figure G20-1). In addition, all features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the Earth-facing component to the location of the feature on the row-facing strip.

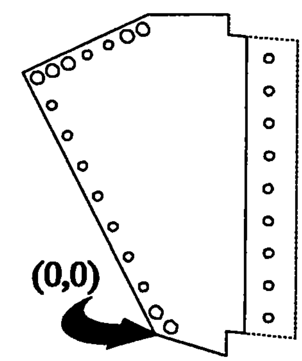

Figure G20-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel G20.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.G20	RE000001.G20	-80	950		ND	Al	*1,3*
LE000002.G20	RE000002.G20	60	197		0.8 x 0.6	Al	*1*
LE000003.G20	RE000003.G20	111	119	153	1.1	Al	*2*
LE000004.G20	RE000004.G20	111	378	148	0.6	Al	*2*
LE000005.G20	RE000005.G20	111	685	13	0.7	Al	*2*
LE000006.G20	RE000006.G20	111	731	152	1.1	Al	*2*
LE000007.G20	RE000007.G20	111	932	128	1.9	Al	*2,d*
AE000007.G20	BE000007.G20	111	932	128	1.9	Al	*2,4*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Feature located Earth-facing component of thermal panel.
2 - Feature located on Row 7-facing strip of thermal panel.
3 - Highly oblique feature.
4 - Lower Magnification view of image LE000007.G20.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-deintegration
Post Deintegration - KSC-390C-3509.05 and KSC-390C-3509.06
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - G20S01F

LDEF LOCATION:	**G21**
EXPERIMENT TITLE:	**THERMAL CONTROL PANEL**
PRINCIPAL INVESTIGATOR:	**W.M. BERRIOS**
	434 NASA LANGLEY RESEARCH CENTER
	HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel G21 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (Earth-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 8-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the Earth-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 8-facing direction. Panel G21 was attached to the spacecraft by nineteen 303 stainless steel bolts (ten on the Earth-facing side and nine on the Row 8-facing strip). An ~3" in diameter red reflector was attached to a 0.062" (1.6 mm) thick, chromic-anodized aluminum plate which in turn, was attached to the thermal panel at bolt locations G21S01E and G21S01F on the Row 8-facing strip.

Detailed examination of Thermal Panel G21 revealed 118 features, 109 of which were <0.5 mm in diameter and were not photodocumented (four on the Earth-facing component and 105 on the Row 8-facing strip, including four features on the anodized aluminum plate behind the reflector and one on top of a 303, stainless-steel, hex-head bolt [G21S01I]). Of the remaining nine features that were photodocumented, seven resided on the Row 8-facing strip (one [~1.1 mm in diameter] on the reflector base plate), four of which were between 0.5 and 1.0 mm in diameter, one that measured ~1.4 mm in diameter, and one measuring ~1.5 mm in diameter that was the largest feature discovered on panel G21. The morphology of all features discussed to this point were typical of craters produced in similar material under controlled, laboratory condition. No diameters were determine for the two features residing on the Earth-facing component of panel G21, both of which were highly oblique in nature. These highly oblique features generally appeared as little more than streaks or scratches until examined under the microscope. Such features were not uncommon on the various Earth-end thermal panels and, in general, possessed semi-minor axes of <0.5 mm, while the semi-major axes were commonly measured at >1.0 mm in length.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 8-FACING STRIP	EARTH-FACING COMPONENT	TOTALS
<0.5 mm	5	100	4	109
>0.5 mm	1	6	2	9
TOTALS	6	106	6	118

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel G21 was conducted on March 29, 1990 and revealed no features on the panel's surface near the bolts, or on the bolts themselves that could be damaged as a result of removing the panel from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel G21 was conducted on April 23, 1990. Both the Earth-facing component and the Row 8-facing strip were photodocumented (in the horizontal and vertical mode, respectively) with M&D SIG System #1 and Coordinate Registration System #3. The bolts associated with this thermal panel were scanned with M&D SIG System #1, while the reflector was scanned and imaged utilizing M&D SIG System #2. As a result of the standard adopted by the M&D SIG A-Team for the assignment of the (0,0) reference point for all hardware removed from the LDEF spacecraft (see Section 2.C.6.a), Earth-end thermal panels received (0,0) reference points that often lead to neagative X- or Y-coordinate values for some features (Figure G14-1). In addition, all features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the Earth-facing component to the location of the feature on the row-facing strip.

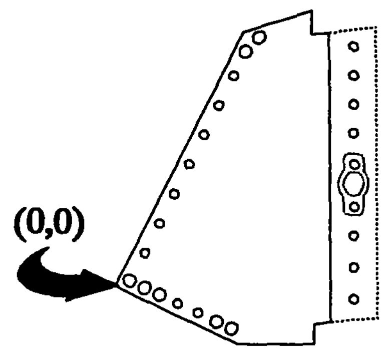

Figure G21-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel G21.

Impact Features Imaged on Thermal Panel Bolts and Reflectors

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LR210001.G21	RR210001.G21	15	9		1.1	Al	

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.G21	RE000001.G21	295	391		ND	Al	*1,2*
LE000002.G21	RE000002.G21	398	437		ND	Al	*1,2*
LE000003.G21	RE000003.G21	569	-83	8	0.6	Al	*3*
LE000004.G21	RE000004.G21	569	309	68	0.6	Al	*3*
LE000005.G21	RE000005.G21	569	701	78	1.3	Al	*3*
LE000006.G21	RE000006.G21	569	731	82	1.5	Al	*3*
LE000007.G21	RE000007.G21	569	754	90	0.6	Al	*3*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000008.G21	RE000008.G21	569	-153	24	0.6	Al	*3*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Feature located on Earth-facing component of thermal panel.
2 - Highly-oblique feature.
3 - Feature located on Row 8-facing strip of thermal panel.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration - KSC-390C-3417.05, KSC-390C-3510.10, and KSC-390C-3510.11
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - G21S01I

LDEF LOCATION: G22
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR:
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HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel G22 was one of four approximately rectangular-shaped thermal panels adjacent to Rows 3, 6, 9, and 12, respectively (Earth-facing component measuring ~24" x 39" [61 x 99.5 cm], while the Row 9-facing strip measured ~6.25" x 39" [15.9 x 99.5]). The total exposed surface area of the rectangular-shaped thermal panels was ~1,180 in^2 (~7,673 cm^2), approximately 936 in^2 (~6,091 cm^2) of which was in the Earth-facing direction and ~244 in^2 (~1,582 cm^2) of which was in the Row 9-facing direction. Panel G22 was attached to the spacecraft by twenty-one 303 stainless steel bolts (12 on the Earth-facing side and nine on the Row 9-facing strip). An ~3" in diameter red reflector was attached to a 0.062" (1.6 mm) thick, chromic-anodized aluminum plate which in turn, was attached to the thermal panel at bolt locations G22S01P and G22S01Q on the Earth-facing component.

Detailed examination of Thermal Panel G22 revealed 139 features, 128 of which were <0.5 mm in diameter and were not photodocumented (11 on the Earth-facing component and 117 on the Row 9-facing strip). Of the remaining 11 features, ten were between 0.5 and 1.0 mm in diameter, nine of which resided on the Row 9-facing strip. One other feature, the largest on panel G22, was photodocumented on the Row 9-facing strip measuring ~1.2 mm diameter. The one photodocumented feature on the Earth-facing component was highly oblique in nature. Such highly-obliques features were not uncommon on the various Earth-end thermal panels and, in general, possessed semi-minor axes of <0.5 mm, while the semi-major axes were commonly measured at >1.0 mm in length. Other than the one oblique feature, the morphology of the remaining craters examined on this thermal control panel was typical of craters formed in similar material under controlled, laboratory conditions.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 9-FACING STRIP	EARTH-FACING COMPONENT	TOTALS
<0.5 mm		117	11	128
>0.5 mm		10	1	11
TOTALS		127	12	139

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel G22 was conducted on March 29, 1990 and revealed no features on the panel's surface near the bolts, or on the bolts themselves that could be damaged as a result of removing the panel from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel G22 was conducted on April 23, 1990. The Earth-facing end of the panel was examined and photodocumented in the horizontal position, while the Row 9-facing strip was examined and photodocumented in the vertical mode. Imaged feature were photodocumented utilizing M&D SIG System #1 and Coordinate Registration System #3. The bolts and reflector associated with this thermal panel were scanned with M&D SIG System #1. As a result of the standard adopted by the M&D SIG A-Team for the assignment of the (0,0) reference point for all hardware removed from the LDEF spacecraft (see Section 2.C.6.a), Earth-end thermal panels received (0,0) reference points that often lead to neagative X- or Y-coordinate values for some features (Figure G22-1). In addition, all features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the Earth-facing component to the location of the feature on the row-facing strip.

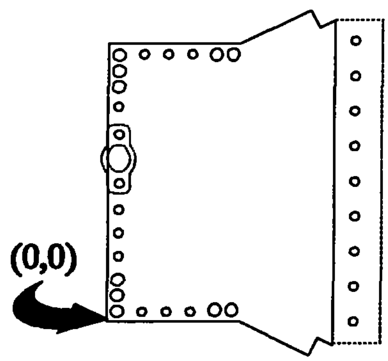

Figure G22-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel G22.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.G22	RE000001.G22	260	250		ND	Al	*1,2*
LE000002.G22	RE000002.G22	631	200	148	1.2	Al	*3*
LE000003.G22	RE000003.G22	631	503	127	0.6	Al	*3*
LE000004.G22	RE000004.G22	631	633	10	0.9	Al	*3,4*
LE000005.G22	RE000005.G22	631	909	97	0.7	Al	*3*
LE000006.G22	RE000006.G22	631	970	80	0.6	Al	*3*
LE000007.G22	RE000007.G22	631	925	48	0.5	Al	*3*
LE000008.G22	RE000008.G22	631	565	20	0.5	Al	*3*
LE000009.G22	RE000009.G22	631	544	71	0.6	Al	*3*
LE000010.G22	RE000010.G22	631	478	45	0.5	Al	*3*
LE000011.G22	RE000011.G22	631	432	20	0.5	Al	*3*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Feature located on Earth-facing component of thermal panel.
2 - Highly-oblique feature.
3 - Feature located on Row 9-facing strip of thermal panel.
4 - Feature covered with a whitish colored material of unknown origins.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration - KSC-390C-3417.04, KSC-390C-3509.01, and KSC-390C-3501.02
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION: G23
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W.M. BERRIOS
434 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel G23 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (Earth-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 10-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the Earth-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 10-facing direction. Panel G23 was attached to the spacecraft by nineteen 303 stainless steel bolts (ten on the Earth-facing side and nine on the Row 10-facing strip). An ~3" in diameter red reflector was attached to a 0.062" (1.6 mm) thick, chromic-anodized aluminum plate which in turn, was attached to the thermal panel at bolt locations G23S01E and G23S01F on the Row 10-facing strip.

Detailed examination of Thermal Panel G23 revealed 161 features, of which were <0.5 mm in diameter and were not photodocumented (15 on the earth-facing component, 116 on the Row 10-facing strip, and 14 on the green reflector). Of the 16 remaining impacts one resided on the earth-facing component which was a small oblique impact ~0.5 x 0.3 mm in diameter. The ten imaged impacts residing on the Row 10-facing strip ranged in diameter from 0.6 mm to 2.1 mm with the later being the largest impact on the thermal panel which almost penetrated through the 0.062" (1.6 mm) thick aluminum. Three impacts were imaged on the reflector and ranged in size from 0.2 mm to 0.8 mm in diameter. Of the 16 impact features photo documented two were highly oblique impacts, located on the Earth-facing component, and appeared as nothing more than streaks or scratches until examined under the microscope. Such highly-oblique features were not uncommon on the various Earth-end thermal panels and, in general, possessed semi-minor axes of <0.5 mm, while the semi-major axes were commonly measured at >1.0 mm in length.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 10-FACING STRIP	EARTH-FACING COMPONENT	TOTALS
<0.5 mm	15	116	18	149
>0.5 mm	2	10		12
TOTALS	17	126	18	161

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel G23 was conducted on March 29, 1990 and revealed no features on the panel's surface near the bolts, or on the bolts themselves that could be damaged as a result of removing the panel from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel G23 was conducted on April 23, 1990. Both the Earth-facing component and the Row 10-facing strip were photodocumented (in the horizontal and vertical mode, respectively) using M&D SIG System #2 and the coordinates were documented using Coordinate Registration System #3. The bolts and reflector associated with this thermal panel were scanned with M&D SIG System #1. As a result of the standard adopted by the M&D SIG A-Team for the assignment of the (0,0) reference point for all hardware removed from the LDEF spacecraft (see Section 2.C.6.a), Earth-end thermal panels received (0,0) reference points that often lead to negative X- or Y- coordinate values for some features (Figure G23-1). In addition, all features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the Earth-facing component to the location of the feature on the row-facing strip.

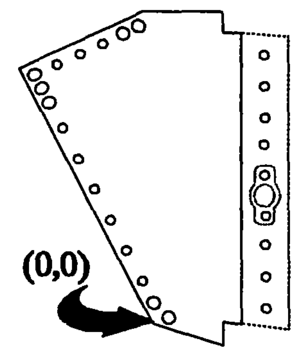

Figure G23-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel G23.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.G23	RE000001.G23	32	293		0.5 x 0.3	Al	*1,3*
LE000002.G23	RE000002.G23	-6	1016		ND	Al	*1,3*
LE000003.G23	RE000003.G23	74	653		ND	Al	*1,3*
LE000004.G23	RE000004.G23	110	251	135	0.6	Al	*2*
AE000004.G23	BE000004.G23	110	251	135	0.6	Al	*2,4*
LE000005.G23	RE000005.G23	110	519	28	0.6	Al	*2*
AE000005.G23	BE000005.G23	110	519	28	0.6	Al	*2,5*
LE000006.G23	RE000006.G23	110	638	28	0.7	Al	*2*
LE000007.G23	RE000007.G23	110	604	65	0.6	Al	*2*
LE000008.G23	RE000008.G23	110	588	135	0.6	Al	*2*
LE000009.G23	RE000009.G23	110	826	78	1.0	Al	*2*
LE000010.G23	RE000010.G23	110	858	33	0.8	Al	*2*
LE000011.G23	RE000011.G23	110	885	30	0.7	Al	*2*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000012.G23	RE000012.G23	110	959	76	0.7	Al	*2*
LE000013.G23	RE000013.G23	110	1015	14	2.1	Al	*2,6*
LG230001.G23	RG230001.G23	138	21		0.7	Al	*7*
LG230002.G23	RG230002.G23	134	5		0.2	Al	*7*
LG230003.G23	RG230003.G23	42	52		0.5	Al	*7*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Feature located Earth-facing component of thermal panel.
2 - Feature located on Row 10-facing strip of thermal panel.
3 - Highly oblique feature.
4 - Not documented why the second image was taken of image LE000004.G23.
5 - Not documented why the second image was taken of image LE000005.G23.
6 - Very large impact, almost penetrated the 0.062" (1.6 mm) thick thermal panel.
7 - Feature located on reflector. Incorrect file name stored with image should be LE000001.R01, RE000001.R01.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-deintegration
Post Deintegration - KSC-390C-3417.03, KSC-390C-3511.07, and KSC-390C-3511.08
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION: G24
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W.M. BERRIOS
434 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel G24 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (Earth-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 11-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the Earth-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 11-facing direction. Panel G24 was attached to the spacecraft by eighteen 303 stainless steel bolts (nine on the Earth-facing side and nine on the Row 11-facing strip).

Detailed examination of Thermal Panel G24 revealed 121 features, 114 of which were <0.5 mm in diameter and were not photodocumented (six on the earth-facing component and 108 on the Row 11-facing strip). Of the seven remaining impacts one resided on the earth-facing component which was a small oblique impact 0.2 mm in diameter. Two circular impact features resided on the Row 11-facing strip measuring ~0.6 mm and ~0.9 mm, the later being the largest impact on the thermal panel. Of the seven features photo documented four were highly oblique impact, located on the Earth-facing component, and appeared as nothing more than streaks or scratches until examined under the microscope. Such highly-oblique features were not uncommon on the various Earth-end thermal panels and, in general, possessed semi-minor axes of <0.5 mm, while the semi-major axes were commonly measured at >1.0 mm in length.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 11-FACING STRIP	EARTH-FACING COMPONENT	TOTALS
<0.5 mm		108	11	119
>0.5 mm		2		2
TOTALS		110	11	121

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel G24 was conducted on March 29, 1990 and revealed no features on the panel's surface near the bolts, or on the bolts themselves that could be damaged as a result of removing the panel from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel G24 was conducted on April 16, 1990. Both the Earth-facing component and the Row 11-facing strip were photodocumented (in the horizontal and vertical mode, respectively) using M&D SIG System #2 and the coordinates were documented using Coordinate Registration System #3. The bolts and reflector associated with this thermal panel were scanned with M&D SIG System #1. As a result of the standard adopted by the M&D SIG A-Team for the assignment of the (0,0) reference point for all hardware removed from the LDEF spacecraft (see Section 2.C.6.a), Earth-end thermal panels received (0,0) reference points that often lead to negative X- or Y- coordinate values for some features (Figure G24-1). In addition, all features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the Earth-facing component to the location of the feature on the row-facing strip.

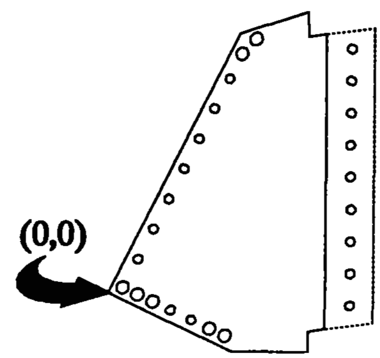

Figure G24-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel G24.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.G24	RE000001.G24	244	62		0.2	Al	*1,3*
LE000002.G24	RE000002.G24	502	466		ND	Al	*1,3*
LE000003.G24	RE000003.G24	425	395		ND	Al	*1,3*
LE000004.G24	RE000004.G24	362	272		ND	Al	*1,3*
LE000005.G24	RE000005.G24	415	26		ND	Al	*1,3*
LE000006.G24	RE000006.G24	569	-156	26	0.6	Al	*2*
LE000007.G24	RE000007.G24	561	-741	145	0.8	Al	*2*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Feature located Earth-facing component of thermal panel.
2 - Feature located on Row 11-facing strip of thermal panel.
3 - Highly oblique feature.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-deintegration
Post Deintegration - KSC-390C-3511.01 and KSC-390C-3511.02
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION:	**H13**
EXPERIMENT TITLE:	**THERMAL CONTROL PANEL**
PRINCIPAL INVESTIGATOR:	**W. M. BERRIOS**
	434 NASA LANGLEY RESEARCH CENTER
	HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel H13 was one of four approximately rectangular-shaped thermal panels adjacent to Rows 3, 6, 9, and 12, respectively (space-facing component measuring ~24" x 39" [61 x 99.5 cm], while the Row 12-facing strip measured ~6.25" x 39" [15.9 x 99.5]). The total exposed surface area of the rectangular-shaped thermal panels was ~1,180 in^2 (~7,673 cm^2), approximately 936 in^2 (~6,091 cm^2) of which was in the space-facing direction and ~244 in^2 (~1,582 cm^2) of which was in the Row 12-facing direction. Panel H13 was attached to the spacecraft by nineteen 303 stainless steel bolts (12 on the space-facing side and seven on the Row 12-facing strip). An ~3" in diameter amber reflector was attached to a 0.062" (1.6 mm) thick, chromic-anodized aluminum plate which in turn, was attached to the thermal panel at bolt locations H13S01O and H13S01P on the Row 12-facing strip.

Detailed examination of Thermal Panel H13 by the M&D SIG A-Team visually identified 267 impact features. Two hundred forty three of these impacts were <0.5 mm in diameter; 199 of these were on the space-facing component (one of which was photodocumented), 41 were on the Row 12-facing strip, and three were on the reflector. Twenty impact features were between 0.5 mm and 1.0 mm in diameter; 15 of these were on the space-facing component, four were on the Row 12-facing strip (one of which was an ejecta spray pattern from the large impact into the reflector mounted on this strip of the thermal panel), and one was on the reflector. Three of the impact features were between 1.0 mm and 1.5 mm in diameter; one of these was on the space-facing component. One impact on the space-facing component was between 1.5 mm and 2.0 mm in diameter. None of the highly-oblique features observed by the M&D SIG A-Team on the Earth-end thermal panels were discovered on the space-end thermal panels while at Kennedy Space Center. A more detailed, microscopic examination of the space-end thermal panels is being conducted at Langley Research Center in search of highly-oblique features. Morphologically, all features examined on this thermal control panel were typical of craters produced in aluminum during controlled laboratory hypervelocity impact tests.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 12-FACING STRIP	SPACE-FACING COMPONENT	TOTALS
<0.5 mm	3	41	199	243
>0.5 mm	1	6	17	24
TOTALS	4	47	216	267

The largest impact features identified were (1) an ~1.5 mm diameter crater located on the space-facing component surface, (2) an ~1.2 mm diameter crater in the Row 12-facing strip, and (3) an ~0.7 mm crater on the reflector which was mounted to the Row 12-facing strip.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel H13 was conducted on March 29, 1990 and identified six features, near bolts H13B, H133, H136, H137, H1310, and H13Q, which might be damaged by removal of the panel from the spacecraft. One possible feature was also identified on the side of bolt H132. A request for Ground Operations personnel to use special care in the removal of this bolt was made by the M&D SIG A-Team.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.0625" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

The detailed examination and photodocumentation of Thermal Control Panel H13 was conducted on April 17, 1990. The space-facing component of the panel was examined and photodocumented in the horizontal position utilizing M&D SIG System #1. The Row 12-facing strip was examined and photodocumented in the vertical position utilizing M&D SIG System #3. The coordinates of features were measured using M&D SIG Coordinate Registration System #3. The bolts and reflector associated with this tray were scanned and imaged with M&D SIG System #2; the coordinates for features residing on the reflector were measured with a metric scale. The (0,0) reference point for all space-end thermal panels was at the lower left-hand corner of the panel at the intersection of the space-facing and row-facing surfaces (Figure H13-1). All features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the space-facing component to the location of the feature on the row-facing strip. Due to a computer error in M&D SIG System #1, the first twenty eight images of this thermal panel were not usable and had to be retaken. For this reason, the first image number is #29.

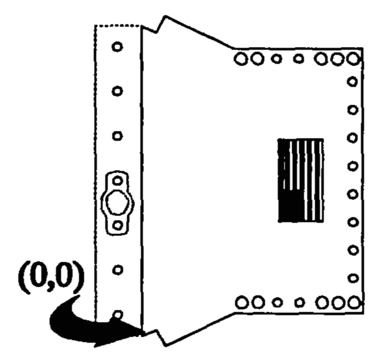

Figure H13-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel H13.

Impact Features Imaged on Exposed Thermal Panel and Reflector Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000029.H13	RE000029.H13	149	42		0.4 x 0.5	Al	1
LE000030.H13	RE000030.H13	128	261		0.5	Al	1
LE000031.H13	RE000031.H13	91	588		0.5	Al	1
LE000032.H13	RE000032.H13	100	753		0.8	Al	1
LE000033.H13	RE000033.H13	241	32		0.8	Al	1

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000034.H13	RE000034.H13	297	446		0.8 x 0.9	Al	*1,d*
LE000035.H13	RE000035.H13	332	460		0.3 x 0.4	Al	*1,d*
LE000036.H13	RE000036.H13	315	540		0.6	Al	*1*
LE000037.H13	RE000037.H13	236	701		0.5	Al	*1*
LE000038.H13	RE000038.H13	279	990		0.7	Al	*1*
LE000039.H13	RE000039.H13	469	297		0.7	Al	*1*
AE000040.H13	BE000040.H13	469	329		0.5	Al	*1,6*
LE000041.H13	RE000041.H13	440	521		1.0	Al	*1*
EE000042.H13	FE000042.H13	464	614		0.6	Al	*1*
LE000043.H13	RE000043.H13	562	6		0.5	Al	*1*
LE000044.H13	RE000044.H13	580	152		1.5	Al	*1*
LE000045.H13	RE000045.H13	615	520		0.6	Al	*1*
LE000046.H13	RE000046.H13	558	516		0.5	Al	*1,2*
LE000047.H13	RE000047.H13	0	129	65	1.2	Al	*3,z*
LE000048.H13	RE000048.H13	0	190	11	1.0	Al	*3,z*
LE000049.H13	RE000049.H13	0	169	151	0.7	Al	*3,z*
AE000050.H13	BE000050.H13	0	360	155		Al	*3,4,6,z*
CE000051.H13	DE000051.H13	0	344	34	1.0	Al	*3,6,z*
CE000052.H13	DE000052.H13	0	631	128	1.2	Al	*3,6,z*
LR130001.H13	RR130001.H13	139	5		0.7	Al	*5,e*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Feature located on space-facing component.
2 - Impact into red stripe of American flag decal.
3 - Feature located on Row 12-facing strip.
4 - Ejecta spray pattern caused by impact into edge of reflector.
5 - Impact located on edge of reflector; crater is only a half crater due to edge impact and created ejecta spray on Row 12-facing strip of Thermal Control Panel H13.
6 - Prior images bad due to computer failure.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration - KSC-390C-3417.11, KSC-390C-3413.02, and KSC-390C-3413.04
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION: H14
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W.M. BERRIOS

434 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel H14 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (space-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 1-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the space-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 1-facing direction. Panel H14 was attached to the spacecraft by eighteen 303 stainless steel bolts (nine on the space-facing side and nine on the Row 1-facing strip).

Detailed examination of Thermal Panel H14 revealed 141 features, of which 131 were <0.5 mm in diameter and were not photodocumented (104 on the space-facing component and 27 on the Row 1-facing strip). Of the 10 remaining impacts eight resided on the space-facing component which ranged in size from 0.6 mm to 1.1 mm the latter being the largest impact found on the thermal panel H14. The two imaged impacts residing on the Row 1-facing strip measured ~0.5 x 0.5 mm and ~0.8 mm in diameter, respectively. None of the highly-oblique feature observed by the M&D SIG A-Team on the various Earth-end thermal panels were discovered on the space-end thermal panels while at KSC. A more detailed, microscopic examination of the space-end thermal panels is being conducted at NASA Langley Research Center in search of highly-oblique features. Morphologically, the craters examined on this thermal-control panel were typical of impact craters formed in similar material under controlled, laboratory conditions.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 1-FACING STRIP	SPACE-FACING COMPONENT	TOTALS
<0.5 mm		27	104	131
>0.5 mm		2	8	10
TOTALS		29	112	141

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel H14 was conducted on March 29, 1990 and revealed two features near bolts, one near Bolt H14D and one near H145 on the Space-facing end of the thermal panel that might be damaged by the removal of the panel from the spacecraft. A request for Ground Operations personnel to use special care in the removal of this bolt was made by the M&D SIG.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel H14 was conducted on April 17, 1990. Both the space-facing component and the Row 1-facing strip were photodocumented (in the horizontal and vertical mode, respectively) using M&D SIG System #2 and the coordinates were documented using Coordinate Registration System #3. The bolts and reflector associated with this thermal panel were scanned with M&D SIG System #1. The (0,0) reference point for all space-end thermal panels was at the low left-hand corner of the panel at the intersection of the space-facing and row-facing surfaces (Figure H14-1). All features photodocumented on the carious row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the space-facing component to the location of the feature on the row-facing strip.

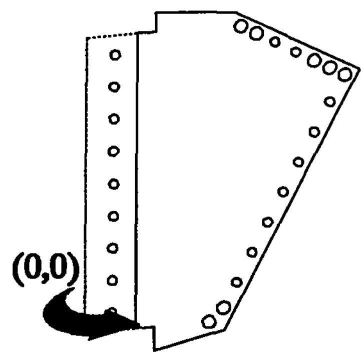

Figure H14-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel H14.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.H14	RE000001.H14	127	304		0.8	Al	1
LE000002.H14	RE000002.H14	120	404		0.8	Al	1
LE000003.H14	RE000003.H14	30	826		0.6	Al	1
LE000004.H14	RE000004.H14	52	930		1.0	Al	1
LE000005.H14	RE000005.H14	120	966		0.7	Al	1
LE000006.H14	RE000006.H14	382	554		0.8	Al	1
LE000007.H14	RE000007.H14	515	774		1.1	Al	1
LE000008.H14	RE000008.H14	60	902		0.5	Al	1
AE000008.H14	BE000008.H14	60	902		0.5	Al	1
LE000009.H14	RE000009.H14	0	314	50	0.8	Al	2

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
AE000009.H14	BE000009.H14	0	314	50	0.8	Al	*w,2,3*
LE000010.H14	RE000010.H14	0	314	50	0.8	Al	*w,2,3*
LE000011.H14	RE000011.H14	0	665	11	0.5 x 0.5	Al	*w,2*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Feature located space-facing component of thermal panel.
2 - Feature located on Row 1-facing strip of thermal panel.
3 - Not documented why second photo was taken of image LE000009.H14.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-deintegration
Post Deintegration - KSC-390C-3415.06 and KSC-390C-3415.07
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION:	**H15**
EXPERIMENT TITLE:	**THERMAL CONTROL PANEL**
PRINCIPAL INVESTIGATOR:	**W.M. BERRIOS**
	434 NASA LANGLEY RESEARCH CENTER
	HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel H15 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (space-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 2-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the space-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 2-facing direction. Panel H15 was attached to the spacecraft by eighteen 303 stainless steel bolts (nine on the space-facing side and nine on the Row 2-facing strip). An ~3" in diameter amber reflector was attached to a 0.062" (1.6 mm) thick, chromic-anodized aluminum plate which in turn, was attached to the thermal panel at bolt locations H15S01O and H15S01N on the Row 2-facing strip.

Detailed examination of Thermal Panel H15 revealed 91 features, 82 of which were <0.5 mm in diameter and were not photodocumented (66 on the space-facing component, 18 on the Row 2-facing strip, and one located on bolt H15J). Of the nine remaining impacts five resided on the space-facing component and ranged in size from 0.5 mm to 0.8 mm the latter being the largest impact found on the space-facing component. The three imaged impacts residing on the Row 2-facing strip ranged in size from 0.5 mm to 1.1 mm in diameter, the largest an oblique ~1.1 x 0.5 mm in diameter. One impact was found on the plastic surface of the amber reflector and measured ~0.7 mm in diameter. None of the highly-oblique feature observed by the M&D SIG A-Team on the various Earth-end thermal panels were discovered on the space-end thermal panels while at KSC. A more detailed, microscopic examination of the space-end thermal panels is being conducted at NASA Langley Research Center in search of highly-oblique features. Morphologically, the craters examined on this thermal-control panel were typical of impact craters formed in similar material under controlled, laboratory conditions.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 2-FACING STRIP	SPACE-FACING COMPONENT	TOTALS
<0.5 mm	1	15	66	82
>0.5 mm	1	3	5	9
TOTALS	2	18	71	91

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel H15 was conducted on March 29, 1990 and revealed no features on the panel's surface near the bolts, or on the bolts themselves that could be damaged as a result of removing the panel from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel H15 was conducted on April 17, 1990. Both the space-facing component and the Row 2-facing strip were photodocumented (in the horizontal and vertical mode, respectively) using M&D SIG System #2 and the coordinates were documented using Coordinate Registration System #3. The bolts and reflector associated with this thermal panel were scanned with M&D SIG System #1. The (0,0) reference point for all space-end thermal panels was at the low left-hand corner of the panel at the intersection of the space-facing and row-facing surfaces (Figure H15-1). All features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the space-facing component to the location of the feature on the row-facing strip.

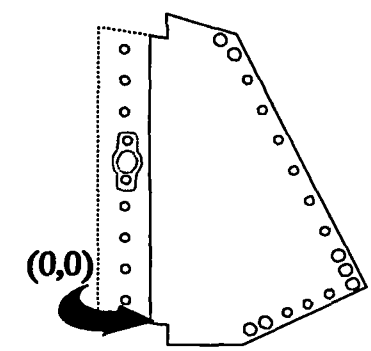

Figure H15-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel H15.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.H15	RE000001.H15	0	501	81	1.1 x 0.5	Al	*1,z*
LE000002.H15	RE000002.H15	0	713	125	0.8	Al	*z,1*
LE000003.H15	RE000003.H15	0	162	148	0.5	Al	*z,1*
LE000004.H15	RE000004.H15	61	374		0.7	Al	*2*
LE000005.H15	RE000005.H15	228	530		0.8	Al	*2*
AE000005.H15	BE000005.H15	228	530		0.8	Al	*2,4*
CE000005.H15	DE000005.H15	228	530		0.8	Al	*2,4*
EE000005.H15	FE000005.H15	228	530		0.8	Al	*2,4*
LE000006.H15	RE000006.H15	134	320		0.5	Al	*2*
AE000006.H15	BE000006.H15	134	320		0.5	Al	*2,5*
LE000007.H15	RE000007.H15	153	471		0.5	Al	*2*
LE000008.H15	RE000008.H15	169	692		0.5	Al	*2*
AE000008.H15	BE000008.H15	169	692		0.5	Al	*2,6*
LR150001.H15	RR150001.H15	65	46		0.7	Plastic	*3*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Feature located on Row 2-facing strip of thermal panel..
2 - Feature located on space-facing component of thermal panel.
3 - Feature located on reflector.
4 - Not documented why second photo was taken of image LE000005.H15.
5 - Not documented why second photo was taken of image LE000006.H15
6 - Not documented why second photo was taken of image LE000008.H15

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-deintegration
Post Deintegration - KSC-390C-3418.05, KSC-390C-3415.02, and KSC-390C-3415.03
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - H15S01J

LDEF LOCATION:	**H16**
EXPERIMENT TITLE:	**THERMAL CONTROL PANEL**
PRINCIPAL INVESTIGATOR:	**W.M. BERRIOS**
	434 NASA LANGLEY RESEARCH CENTER
	HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel H16 was one of four approximately rectangular-shaped thermal panels adjacent to Rows 3, 6, 9, and 12, respectively (space-facing component measuring ~24" x 39" [61 x 99.5 cm], while the Row 3-facing strip measured ~6.25" x 39" [15.9 x 99.5]). The total exposed surface area of the rectangular-shaped thermal panels was ~1,180 in^2 (~7,673 cm^2), approximately 936 in^2 (~6,091 cm^2) of which was in the space-facing direction and ~244 in^2 (~1,582 cm^2) of which was in the Row 3-facing direction. Panel H16 was attached to the spacecraft by nineteen 303 stainless steel bolts (ten on the space-facing side and nine on the Row 3-facing strip).

Detailed examination of Thermal Panel H16 revealed 142 features, 123 of which were <0.5 mm in diameter and were not photodocumented (115 on the space-facing component and eight on the Row 3-facing strip). Seventeen of the remaining 19 features that were photodocumented ranged in size between 0.5 and 1.0 mm in diameter (16 on the space-facing component and one on the Row 3-facing strip). One additional feature was photodocumented on the both space-facing component and the Row 3-facing strip (~1.2 and ~1.9 mm in diameter, respectively), the latter representing the largest feature on the H16 thermal panel. None of the highly-oblique feature observed by the M&D SIG A-Team on the various Earth-end thermal panels were discovered on the space-end thermal panels while at KSC. A more detailed, microscopic examination of the space-end thermal panels is being conducted at LaRC in search of highly-oblique features. Morphologically, the craters examined on this thermal-control panel were typical of impact craters formed in similar material under controlled, laboratory conditions.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 3-FACING STRIP	SPACE-FACING COMPONENT	TOTALS
<0.5 mm		8	115	123
≥0.5 mm		2	17	19
TOTALS		10	132	142

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel H16 was conducted on March 29, 1990 and revealed one feature near Bolt H16S01T on the Row 3-facing strip of the thermal panel that might be damaged by the removal of the panel from the spacecraft. A request for Ground Operations personnel to use special care in the removal of this bolt was made by the M&D SIG.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel H16 was conducted on April 23, 1990. The space-facing end of the panel was examined and photodocumented in the horizontal position, while the Row 3-facing strip was examined and photodocumented in the vertical mode. Imaged features were photodocumented utilizing M&D SIG System #1 and Coordinate Registration System #3. The bolts associated with this thermal panel were scanned with M&D SIG System #1. The (0,0) reference point for all space-end thermal panels was at the low left-hand corner of the panel at the intersection of the space-facing and row-facing surfaces (Figure H16-1). All features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the space-facing component to the location of the feature on the row-facing strip.

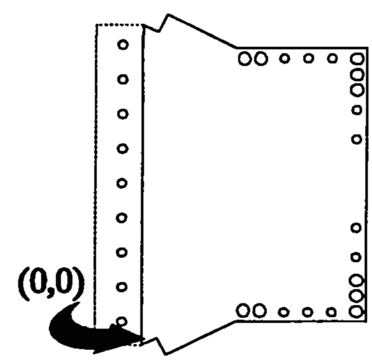

Figure H16-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel H16.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.H16	RE000001.H16	163	178		0.6 x 0.8	Al	*1,d*
LE000002.H16	RE000002.H16	88	234		0.7 x 0.8	Al	*1*
LE000003.H16	RE000003.H16	159	520		1.2	Al	*1*
LE000004.H16	RE000004.H16	6	569		0.6	Al	*1,3*
LE000005.H16	RE000005.H16	87	840		0.6	Al	*1*
LE000006.H16	RE000006.H16	24	1003		0.6	Al	*1*
LE000007.H16	RE000007.H16	562	908		0.6	Al	*1*
LE000008.H16	RE000008.H16	574	771		0.6	Al	*1*
LE000009.H16	RE000009.H16	552	677		0.6	Al	*1*
LE000010.H16	RE000010.H16	432	620		0.7	Al	*1*
LE000011.H16	RE000011.H16	260	420		0.6	Al	*1*
LE000012.H16	RE000012.H16	471	199		0.5	Al	*1*
LE000013.H16	RE000013.H16	471	156		0.6	Al	*1*
LE000014.H16	RE000014.H16	523	29		0.5	Al	*1*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000015.H16	RE000015.H16	340	85		0.6	Al	*1*
LE000016.H16	RE000016.H16	287	192		0.9	Al	*1*
LE000017.H16	RE000017.H16	592	607		0.6	Al	*1*
LE000018.H16	RE000018.H16	0	867	25	0.9	Al	*2*
LE000019.H16	RE000019.H16	0	86	140	1.9	Al	*2,4*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Feature located on space-facing component of thermal panel.
2 - Feature located on Row 3-facing strip of thermal panel.
3 - Magnification of "5" entered in comments list, should have been "10".
4 - Z-coordinate not entered in comments list.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration - KSC-390C-1030.04, KSC-390C-833.02
Post Deintegration - KSC-390C-3415.10 and KSC-390C-3415.11
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Reflector - H16R01

LDEF LOCATION: H17
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W.M. BERRIOS

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SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel H17 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (space-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 4-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the space-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 4-facing direction. Panel H17 was attached to the spacecraft by eighteen 303 stainless steel bolts (nine on the space-facing side and nine on the Row 4-facing strip). An ~3" in diameter amber reflector was attached to a 0.062" (1.6 mm) thick, chromic-anodized aluminum plate which in turn, was attached to the thermal panel at bolt locations H17S01O and H17S01N on the Row 4-facing strip.

Detailed examination of Thermal Panel H17 revealed 80 features, 76 of which were <0.5 mm in diameter and were not photodocumented (65 on the space-facing component and 11 on the Row 4-facing strip, including three features on the reflector). The four photodocumented features (three on the space-facing component and one on the Row 4-facing strip) ranged in size from 0.5 to 1.0 mm in diameter, the largest of which measured ~0.8 mm in diameter. Morphologically, the features examined on this panel were typical of craters produced in similar material under controlled, laboratory condition. None of the highly-oblique feature observed by the M&D SIG A-Team on the various Earth-end thermal panels were discovered on the space-end thermal panels while at KSC. A more detailed, microscopic examination of the space-end thermal panels is being conducted at LaRC in search of highly-oblique features.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 4-FACING STRIP	SPACE-FACING COMPONENT	TOTALS
<0.5 mm	3	8	65	76
>0.5 mm		1	3	4
TOTALS	3	9	68	80

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel H17 was conducted on March 29, 1990 and revealed no features on the panel's surface near the bolts, or on the bolts themselves that could be damaged as a result of removing the panel from the spacecraft.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel H17 was conducted on April 23, 1990. Both the space-facing component and the Row 4-facing strip were photodocumented (in the horizontal and vertical mode, respectively) with M&D SIG System #1 and Coordinate Registration System #3. The bolts and reflector associated with this thermal panel were scanned with M&D SIG System #1. The (0,0) reference point for all space-end thermal panels was at the low left-hand corner of the panel at the intersection of the space-facing and row-facing surfaces (Figure H17-1). All features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the space-facing component to the location of the feature on the row-facing strip.

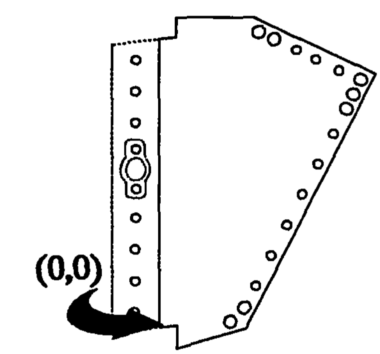

Figure H17-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel H17.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.H17	RE000001.H17	0	811	84	0.8	Al	*1*
LE000002.H17	RE000002.H17	390	708		0.5	Al	*2*
LE000003.H17	RE000003.H17	434	665		0.6	Al	*2*
LE000004.H17	RE000004.H17	126	732		0.8	Al	*2*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Feature located on Row 4-facing strip of thermal panel.
2 - Feature located on space-facing component of thermal panel.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration - KSC-390C-1030.04 and KSC-390C-833.02
Post Deintegration - KSC-390C-3418.04, KSC-390C-3414.08, and KSC-390C-3414.09
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION:	**H18**
EXPERIMENT TITLE:	**THERMAL CONTROL PANEL**
PRINCIPAL INVESTIGATOR:	**W.M. BERRIOS**
	434 NASA LANGLEY RESEARCH CENTER
	HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel H18 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (space-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 5-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the space-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 5-facing direction. Panel H18 was attached to the spacecraft by eighteen 303 stainless steel bolts (nine on the space-facing side and nine on the Row 5-facing strip).

Detailed examination of Thermal Panel H18 revealed 108 features, 91 of which were <0.5 mm in diameter and were not photodocumented (79 on the space-facing component and 12 on the Row 5-facing strip). Of the 17 remaining impacts 14 resided on the space-facing component which ranged in size from 0.5 mm to 1.6 mm the latter being the largest impact found on the thermal panel H18. The three imaged impacts residing on the Row 5-facing strip ranged in diameter from 0.6 mm to 1.0 mm. None of the highly-oblique features observed by the M&D SIG A-Team on the various Earth-end thermal panels were discovered on the space-end thermal panels while at KSC. A more detailed, microscopic examination of the space-end thermal panels is being conducted at LaRC in search of highly-oblique features. Morphologically, the craters examined on this thermal-control panel were typical of impact craters formed in similar material under controlled, laboratory conditions.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 5-FACING STRIP	SPACE-FACING COMPONENT	TOTALS
<0.5 mm		12	79	91
>0.5 mm		3	14	17
TOTALS		15	93	108

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel H18 was conducted on March 29, 1990 and revealed one feature near Bolt H18S017 on the space-facing end of the thermal panel that might be damaged by the

removal of the panel from the spacecraft. A request for Ground Operations personnel to use special care in the removal of this bolt was made by the M&D SIG.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel H18 was conducted on April 16, 1990. Both the space-facing component and the Row 5-facing strip were photodocumented (in the horizontal and vertical mode, respectively) using M&D SIG System #2 and the coordinates were documented using Coordinate Registration System #3. The bolts and reflector associated with this thermal panel were scanned with M&D SIG System #1. The (0,0) reference point for all space-end thermal panels was at the low left-hand corner of the panel at the intersection of the space-facing and row-facing surfaces (Figure H18-1). All features photodocumented on the carious row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the space-facing component to the location of the feature on the row-facing strip.

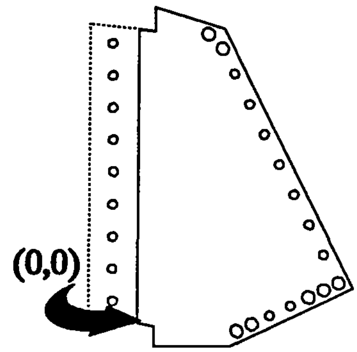

Figure H18-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel H18.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.H18	RE000001.H18	74	401		0.4 x 0.8,0.4	Al	*1,3,4*
LE000002.H18	RE000002.H18	75	77		0.9	Al	*1,d,j*
LE000003.H18	RE000003.H18	26	502		1.6	Al	*1,d*
LE000004.H18	RE000004.H18	58	590		0.8	Al	*1*
LE000005.H18	RE000005.H18	118	792		0.7	Al	*1*
LE000006.H18	RE000006.H18	192	27		0.7 x 1.0	Al	*1,3,5,d,j*
LE000007.H18	RE000007.H18	274	187		0.8	Al	*1,j*
LE000008.H18	RE000008.H18	258	418		0.4 x 0.7	Al	*1,3,d*
LE000009.H18	RE000009.H18	276	494		0.6	Al	*1*
LE000010.H18	RE000010.H18	399	210		0.6	Al	*1*
LE000011.H18	RE000011.H18	490	293		0.5	Al	*1*
LE000012.H18	RE000012.H18	335	285		0.5	Al	*1*
LE000013.H18	RE000013.H18	135	344		0.5	Al	*1*
LE000014.H18	RE000014.H18	95	800		0.5	Al	*1*
LE000015.H18	RE000015.H18	0	158	150	0.5 x 1.0	Al	*2,3,d*
LE000016.H18	RE000016.H18	0	282	146	0.8	Al	*2*
LE000017.H18	RE000017.H18	0	545	78	0.6	Al	*2*
LE000018.H18	RE000018.H18	75	77		0.9	Al	*1,6*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Feature located on space-facing component of thermal panel.
2 - Feature located on Row 5-facing strip of thermal panel.
3 - Oblique feature.
4 - Doublett impact feature.
5 - Photo taken at 12X to show debris spray.
6 - This image file is stored in the computer as LE000018.H24 & RE000018.H24 and is a second photo of image LE000002.H18. This image shows the multi-cratering event and the debris spray of image LE000002.H18.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-deintegration
Post Deintegration - KSC-390C-3414.04 and KSC-390C-3414.05
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION: H19
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W. M. BERRIOS

434 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel H19 was one of four approximately rectangular-shaped thermal panels adjacent to Rows 3, 6, 9, and 12, respectively (space-facing component measuring ~24" x 39" [61 x 99.5 cm], while the Row 6-facing strip measured ~6.25" x 39" [15.9 x 99.5]). The total exposed surface area of the rectangular-shaped thermal panels was ~1,180 in^2 (~7,673 cm^2), approximately 936 in^2 (~6,091 cm^2) of which was in the space-facing direction and ~244 in^2 (~1,582 cm^2) of which was in the Row 6-facing direction. Panel H19 was attached to the spacecraft by nineteen 303 stainless steel bolts (ten on the space-facing side and nine on the Row 6-facing strip). An ~3" in diameter amber reflector was attached to a 0.062" (1.6 mm) thick, chromic-anodized aluminum plate which in turn, was attached to the thermal panel at bolt locations H19S01O and H19S01P on the Row 6-facing strip.

Detailed examination of Thermal Panel H19 by the M&D SIG A-Team visually identified 42 impact features. The thermal panel was not surveyed to identify impacts <0.5 mm in diameter. Twenty four of the 42 impacts were <0.5 mm in diameter; 18 of these were on the space-facing component and were photodocumented, four were on the bolts, and two were on the reflector. Sixteen impact features were between 0.5 mm and 1.0 mm in diameter; 12 of these were on the space-facing component, and four were on the Row 6-facing strip. Two of the impact features were between 1.0 mm and 1.5 mm in diameter; one of these was on the space-facing component. None of the highly-oblique features observed by the M&D SIG A-Team on the Earth-end thermal panels were discovered on the space-end thermal panels while at Kennedy Space Center. A more detailed, microscopic examination of the space-end thermal panels is being conducted at NASA Langley Research Center in search of highly-oblique features. Morphologically, all features examined on this thermal control panel were typical of craters produced in aluminum during controlled laboratory hypervelocity impact tests.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 6-FACING STRIP	SPACE-FACING COMPONENT	TOTALS
<0.5 mm	6		18	24@
>0.5 mm		5	13	18
TOTALS	6	5	31	42

@ - The survey for "Too Smalls" was not conducted.

The largest impact features identified were (1) an ~1.1 mm diameter crater located on the space-facing component surface, (2) an ~1.0 mm diameter crater in the Row 6-facing strip, and (3) an ~0.3 mm crater on the reflector which was mounted to the Row 6-facing strip.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The M&D SIG A-Team did not inspect this thermal control panel prior to its removal from the spacecraft. However, there was no apparent damage noted on any of the impact features examined after its removal from the spacecraft. The panel was removed to allow Ground Operations personnel access to the batteries and initiation system in preparation for putting LDEF into rotation and deintegration mode.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.0625" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

The detailed examination and photodocumentation of Thermal Control Panel H19 was conducted on February 5 and 6, 1990. The space-facing component of the panel was examined and photodocumented in the horizontal position, while the Row 6-facing strip was examined and photodocumented in the vertical position. Both components were photodocumented utilizing M&D SIG System #1. The coordinates of features were measured using M&D SIG Coordinate Registration System #3. The bolts associated with this panel were scanned with M&D SIG System #2, and the reflector which was mounted on the Row 6-facing strip was scanned with M&D SIG System #3. The (0,0) reference point for all space-end thermal panels was at the lower left-hand corner of the panel at the intersection of the space-facing and row-facing surfaces (Figure H19-1). All features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the space-facing component to the location of the feature on the row-facing strip.

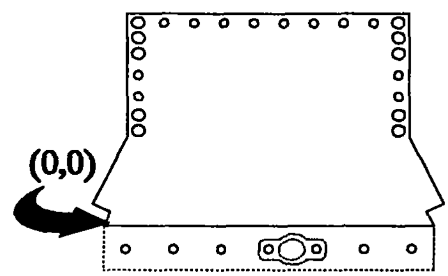

Figure H19-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel H19.

Impact Features Imaged on Exposed Thermal Panel Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.H19	RE000001.H19	233	52		0.4	Al	*1*
LE000002.H19	RE000002.H19	210	65		0.2	Al	*1*
LE000003.H19	RE000003.H19	323	86		0.6	Al	*1*
LE000004.H19	RE000004.H19	898	70		0.5	Al	*1*
LE000005.H19	RE000005.H19	804	100		0.4	Al	*1,k*
LE000006.H19	RE000006.H19	658	129		0.3	Al	*1*
LE000007.H19	RE000007.H19	542	145		0.5	Al	*1*
LE000008.H19	RE000008.H19	202	158		0.9	Al	*1,k*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000009.H19	RE000009.H19	674	168		0.7	Al	*1*
LE000010.H19	RE000010.H19	559	234		0.7	Al	*1*
LE000011.H19	RE000011.H19	461	263		0.7	Al	*1*
LE000012.H19	RE000012.H19	5	305		0.3	Al	*1*
LE000013.H19	RE000013.H19	79	289		1.1	Al	*1*
LE000014.H19	RE000014.H19	319	334		0.9	Al	*1*
LE000015.H19	RE000015.H19	443	352		0.7	Al	*1*
LE000016.H19	RE000016.H19	462	300		0.3	Al	*1*
LE000017.H19	RE000017.H19	496	307		0.4	Al	*1*
LE000018.H19	RE000018.H19	522	290		0.5	Al	*1*
LE000019.H19	RE000019.H19	604	306		0.6	Al	*1*
LE000020.H19	RE000020.H19	603	341		0.4	Al	*1*
LE000021.H19	RE000021.H19	849	359		0.7	Al	*1*
LE000022.H19	RE000022.H19	831	404		0.5	Al	*1*
AE000023.H19	BE000023.H19	595	377		0.4	Al	*1*
LE000023.H19	RE000023.H19	595	377		0.4	Al	*1*
LE000024.H19	RE000024.H19	976	438		0.4	Al	*1,d*
LE000025.H19	RE000025.H19	953	464		0.4	Al	*1,k*
LE000026.H19	RE000026.H19	876	463		0.4	Al	*1*
LE000027.H19	RE000027.H19	891	504		0.4	Al	*1*
LE000028.H19	RE000028.H19	746	463		0.4	Al	*1*
LE000029.H19	RE000029.H19	191	516		0.4	Al	*1*
LE000030.H19	RE000030.H19	220	631		0.9	Al	*1*
LE000031.H19	RE000031.H19	138	1		0.4	Al	*1*
LE000032.H19	RE000032.H19	116	0	102	0.5	Al	*2*
LE000033.H19	RE000033.H19	169	0	28	0.6	Al	*2*
LE000034.H19	RE000034.H19	561	0	89	0.6	Al	*2*
LE000035.H19	RE000035.H19	778	0	60	1.0	Al	*2*
LE000036.H19	RE000036.H19	969	0	86	0.5	Al	*2*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Feature located on space-facing component.
2 - Feature located on Row 6-facing component.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration - KSC-390C-3418.03 (Reflector Only)
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION: H20
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W.M. BERRIOS

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HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel H20 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (space-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 7-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the space-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 7-facing direction. Panel H20 was attached to the spacecraft by eighteen 303 stainless steel bolts (nine on the space-facing side and nine on the Row 7-facing strip).

Detailed examination of Thermal Panel H20 revealed 152 features, 134 of which were <0.5 mm in diameter and were not photodocumented (77 on the space-facing component and 57 on the Row 7-facing strip). Of the remaining 18 features that were photodocumented, the five on the Row 7-facing strip, and 11 of the 13 on the space-facing component ranged in size from 0.5 and 1.0 mm in diameter. The other two photodocumented features both resided on the space-facing component and possessed diameters of ~1.0 and ~1.5 mm, the latter representing the largest feature found on panel H20. Morphologically, the features examined on this panel were typical of craters produced in similar material under controlled, laboratory condition. None of the highly-oblique feature observed by the M&D SIG A-Team on the various Earth-end thermal panels were discovered on the space-end thermal panels while at KSC. A more detailed, microscopic examination of the space-end thermal panels is being conducted at LaRC in search of highly-oblique features.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 7-FACING STRIP	SPACE-FACING COMPONENT	TOTALS
<0.5 mm		57	77	134
>0.5 mm		5	13	18
TOTALS		62	90	152

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel H20 was conducted on March 29, 1990 and revealed two small features (one near Bolt H20S01B and one near Bolt H20S01F) on the space-facing component of the thermal

panel that might be damaged by the removal of the panel from the spacecraft. A request for Ground Operations personnel to use special care in the removal of these bolts was made by the M&D SIG.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel H20 was conducted on April 20, 1990. Both the space-facing component and the Row 7-facing strip were photodocumented (in the horizontal and vertical mode, respectively) with M&D SIG System #1 and Coordinate Registration System #3. The bolts associated with this thermal panel were scanned with M&D SIG System #1. The (0,0) reference point for all space-end thermal panels was at the low left-hand corner of the panel at the intersection of the space-facing and row-facing surfaces (Figure H20-1). All features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the space-facing component to the location of the feature on the row-facing strip.

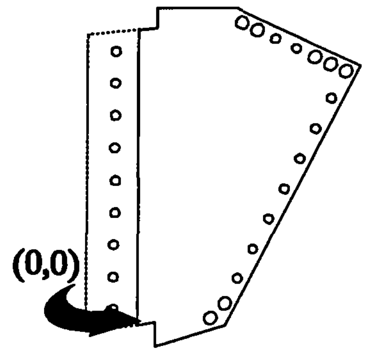

Figure H20-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel H20.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.H20	RE000001.H20	28	101		1.5	Al	*1*
LE000002.H20	RE000002.H20	49	320		0.5	Al	*1*
LE000003.H20	RE000003.H20	185	402		1.0	Al	*1,3*
LE000004.H20	RE000004.H20	233	546		0.6	Al	*1*
LE000005.H20	RE000005.H20	177	815		0.7	Al	*1,4*
LE000006.H20	RE000006.H20	230	930		0.8	Al	*1*
LE000007.H20	RE000007.H20	362	809		1.0	Al	*1*
LE000008.H20	RE000008.H20	405	828		0.8	Al	*1*
LE000009.H20	RE000009.H20	415	818		0.7 x 0.9	Al	*1,d*
LE000010.H20	RE000010.H20	495	678		0.7 x 0.8	Al	*1,d*
LE000011.H20	RE000011.H20	105	981		0.5	Al	*1*
LE000012.H20	RE000012.H20	232	555		0.6	Al	*1*
LE000013.H20	RE000013.H20	183	145		0.5	Al	*1*
LE000014.H20	RE000014.H20	0	341	94	0.6	Al	*2*
LE000015.H20	RE000015.H20	0	456	80	0.8 x 1.0	Al	*2*
LE000016.H20	RE000016.H20	0	550	102	0.9	Al	*2*
LE000017.H20	RE000017.H20	0	539	138	0.7	Al	*2*
LE000018.H20	RE000018.H20	0	965	9	0.7	Al	*2*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Feature located on space-facing component of thermal panel.
2 - Feature located on Row 7-facing strip of thermal panel.
3 - Magnification of "5" entered in comments list, should have been "10".
4 - Diameter of 1.4 mm entered in comments list, should have been 0.7 mm.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration - KSC-390C-1030.04 and KSC-390C-833.02
Post Deintegration - KSC-390C-3416.03 and KSC-390C-3416.04
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION: H21
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W.M. BERRIOS

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SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel H21 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (space-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 8-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the space-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 8-facing direction. Panel H21 was attached to the spacecraft by eighteen 303 stainless steel bolts (nine on the space-facing side and nine on the Row 8-facing strip). An ~3" in diameter amber reflector was attached to a 0.062" (1.6 mm) thick, chromic-anodized aluminum plate which in turn, was attached to the thermal panel at bolt locations H21S01N and H21S01M on the Row 8-facing strip.

Detailed examination of Thermal Panel H21 revealed 146 features, 128 of which were <0.5 mm in diameter and were not photodocumented (70 on the space-facing component and 58 on the Row 8-facing strip, including one feature on the anodized aluminum plate behind the reflector). Of the remaining eighteen features that were photodocumented, ten of the twelve on the Row 8-facing strip, and five of the six on the space-facing component ranged in size between 0.5 and 1.0 mm in diameter. The remaining two features on the Row 8-facing strip measured ~1.2 and ~1.4 mm in diameter and represented the largest features found on panel H21; the one additional feature photodocumented on the space-facing component was ~1.0 mm in diameter. Morphologically, the craters examined on panel H21 were typical of craters formed in similar material under controlled, laboratory conditions. None of the highly-oblique feature observed by the M&D SIG A-Team on the various Earth-end thermal panels were discovered on the space-end thermal panels while at KSC. A more detailed, microscopic examination of the space-end thermal panels is being conducted at LaRC in search of highly-oblique features.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 8-FACING STRIP	SPACE-FACING COMPONENT	TOTALS
<0.5 mm	1	57	70	128
>0.5 mm		12	6	18
TOTALS	1	69	76	146

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel H21 was conducted on March 29, 1990 and revealed one small feature near Bolt H21S017 on the space-facing component of the thermal panel that might be damaged by the removal of the panel from the spacecraft. A request for Ground Operations personnel to use special care in the removal of this bolt was made by the M&D SIG.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel H21 was conducted on April 20, 1990. Both the space-facing component and the Row 8-facing strip were photodocumented (in the horizontal and vertical mode, respectively) with M&D SIG System #1 and Coordinate Registration System #3. The bolts and reflector associated with this thermal panel were scanned with M&D SIG System #1. The (0,0) reference point for all space-end thermal panels was at the low left-hand corner of the panel at the intersection of the space-facing and row-facing surfaces (Figure H20-1). All features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the space-facing component to the location of the feature on the row-facing strip.

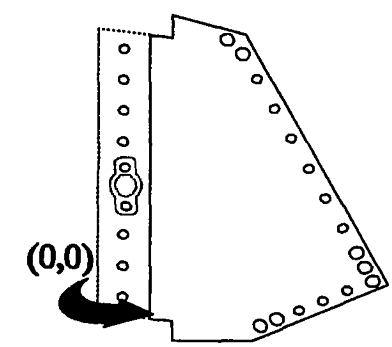

Figure H21-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel H21.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000001.H21	RE000001.H21	7	362		0.7	Al	*1*
LE000002.H21	RE000002.H21	15	598		0.6 x 0.8	Al	*1*
LE000003.H21	RE000003.H21	68	973		1.0	Al	*1*
LE000004.H21	RE000004.H21	474	206		0.7	Al	*1*
LE000005.H21	RE000005.H21	152	293		0.5	Al	*1*
LE000006.H21	RE000006.H21	88	610		0.5	Al	*1*
LE000007.H21	RE000007.H21	0	372	37	1.2	Al	*2,3*
LE000008.H21	RE000008.H21	0	442	33	0.7	Al	*2,3*
LE000009.H21	RE000009.H21	0	490	8	0.7	Al	*2,3*
LE000010.H21	RE000010.H21	0	526	138	0.5	Al	*2,3*
LE000011.H21	RE000011.H21	0	650	15	0.8	Al	*2,3*
LE000012.H21	RE000012.H21	0	710	144	0.7	Al	*2,3*
LE000013.H21	RE000013.H21	0	825	54	1.4	Al	*2,3*
LE000014.H21	RE000014.H21	0	957	13	0.5	Al	*2,3*
LE000015.H21	RE000015.H21	0	812	60	0.6	Al	*2,3*
LE000016.H21	RE000016.H21	0	800	58	0.6	Al	*2,3*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000017.H21	RE000017.H21	0	668	120	0.5	Al	*2,3*
LE000018.H21	RE000018.H21	0	525	138	0.6	Al	*2,3*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Feature located on space-facing component of thermal panel.
2 - Feature located on Row 8-facing strip of thermal panel.
3 - Reference to Row 7-facing strip input into comments list, should have been Row 8.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration - KSC-390C-1030.04 and KSC-390C-833.02
Post Deintegration - KSC-390C-3418.02, KSC-390C-3413.12, and KSC-390C-3414.02
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION: **H22**
EXPERIMENT TITLE: **THERMAL CONTROL PANEL**
PRINCIPAL INVESTIGATOR: **W. M. BERRIOS**

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SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel H22 was one of four approximately rectangular-shaped thermal panels adjacent to Rows 3, 6, 9, and 12, respectively (space-facing component measuring ~24" x 39" [61 x 99.5 cm], while the Row 9-facing strip measured ~6.25" x 39" [15.9 x 99.5]). The total exposed surface area of the rectangular-shaped thermal panels was ~1,180 in^2 (~7,673 cm^2), approximately 936 in^2 (~6,091 cm^2) of which was in the space-facing direction and ~244 in^2 (~1,582 cm^2) of which was in the Row 9-facing direction. Panel H22 was attached to the spacecraft by nineteen 303 stainless steel bolts (ten on the space-facing side and nine on the Row 9-facing strip).

Detailed examination of Thermal Panel H22 by the M&D SIG A-Team visually identified 279 impact features. Two hundred forty nine of these impacts were <0.5 mm in diameter; 139 of these were on the space-facing component, and 110 were on the Row 9-facing strip. Twenty one impact features were between 0.5 mm and 1.0 mm in diameter; 17 of these were on the space-facing component, and four were on the Row 9-facing strip. Six of the impact features were between 1.0 mm and 1.5 mm in diameter; two of these were on the Row 9-facing strip. Two impacts on the Row 9-facing strip were between 1.5 mm and 2.0 mm in diameter, and one impact on this strip was >2.0 mm in diameter. None of the highly-oblique features observed by the M&D SIG A-Team on the Earth-end thermal panels were discovered on the space-end thermal panels while at Kennedy Space Center. A more detailed, microscopic examination of the space-end thermal panels is being conducted at Langley Research Center in search of highly-oblique features. Morphologically, all features examined on this thermal control panel were typical of craters produced in aluminum during controlled laboratory hypervelocity impact tests.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 8-FACING STRIP	SPACE-FACING COMPONENT	TOTALS
<0.5 mm		110	139	249
>0.5 mm		9	21	30
TOTALS		119	160	279

The largest impact features identified were (1) an ~1.5 mm diameter crater located on the space-facing component surface, and (2) an ~2.1 mm diameter crater in the Row 9-facing strip.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel H22 was conducted on March 29, 1990 and identified two features near bolt H22M which might be damaged by removal of the panel from the spacecraft. A request for Ground Operations personnel to use special care in the removal of this bolt was made by the M&D SIG A-Team.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front of the 0.0625" (1.6 mm) thick thermal control panel. However, there were four noticeable bulges and black paint spallations on the back of the thermal control panel.

DOCUMENTATION:

The detailed examination and photodocumentation of Thermal Control Panel H22 was conducted on April 20, 1990. The space-facing component of the panel was examined and photodocumented in the horizontal position utilizing M&D SIG System #2. The Row 9-facing strip was examined and photodocumented in the vertical position, also utilizing M&D SIG System #2. The coordinates of features were measured using M&D SIG Coordinate Registration System #3. The bolts associated with this tray were scanned with M&D SIG System #1. The (0,0) reference point for all space-end thermal panels was at the lower left-hand corner of the panel at the intersection of the space-facing and row-facing surfaces (Figure H22-1). All features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the space-facing component to the location of the feature on the row-facing strip. Due to a computer error in M&D SIG System #1, the first fourteen images of this thermal panel were not usable and had to be re-accomplished. For this reason, the first image number is #15.

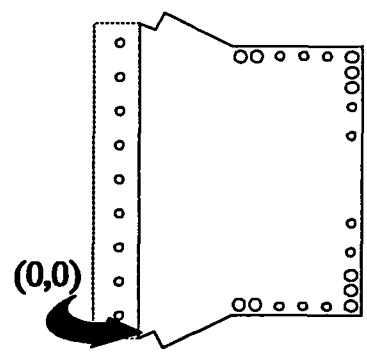

Figure H22-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel H22.

Impact Features Imaged on Exposed Thermal Panel Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000015.H22	RE000015.H22	72	283		0.7	Al	*1*
CE000016.H22	DE000016.H22	67	357		0.4 x 0.7	Al	*1*
LE000017.H22	RE000017.H22	135	295		0.9	Al	*1*
LE000018.H22	RE000018.H22	108	536		1.1	Al	*1*
LE000019.H22	RE000019.H22	46	711		0.6	Al	*1*
LE000020.H22	RE000020.H22	110	780		1.3	Al	*1*
LE000021.H22	RE000021.H22	259	51		0.4 x 0.5	Al	*1*
LE000022.H22	RE000022.H22	227	432		0.5	Al	*1*
LE000023.H22	RE000023.H22	257	525		1.5	Al	*1,2,h,i*
LE000024.H22	RE000024.H22	334	796		0.5	Al	*1*
LE000025.H22	RE000025.H22	301	893		0.6	Al	*1*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000026.H22	RE000026.H22	478	46		1.0	Al	*1*
LE000027.H22	RE000027.H22	469	138		0.8	Al	*1*
LE000028.H22	RE000028.H22	452	189		0.6, 0.8	Al	*1,3*
LE000029.H22	RE000029.H22	477	246		0.7	Al	*1*
LE000030.H22	RE000030.H22	491	258		0.5	Al	*1*
LE000031.H22	RE000031.H22	482	663		0.5	Al	*1*
LE000032.H22	RE000032.H22	468	766		0.6	Al	*1*
LE000033.H22	RE000033.H22	349	925		0.9	Al	*1*
LE000034.H22	RE000034.H22	621	323		0.5	Al	*1*
LE000035.H22	RE000035.H22	535	805		0.5	Al	*1*
LE000036.H22	RE000036.H22	0	12	142	1.7	Al	*2,4,d,h,i*
LE000037.H22	RE000037.H22	0	32	120	1.6	Al	*2,4,h,i*
LE000038.H22	RE000038.H22	0	131	61	0.7	Al	*4*
LE000039.H22	RE000039.H22	0	496	92	2.1	Al	*2,4,h,i*
LE000040.H22	RE000040.H22	0	582	139	1.2	Al	*4*
LE000041.H22	RE000041.H22	0	648	98	1.3	Al	*2,4,h,i*
LE000042.H22	RE000042.H22	0	810	72	0.7	Al	*4*
LE000043.H22	RE000043.H22	0	623	40	0.6	Al	*4*
LE000044.H22	RE000044.H22	0	985	25	1.0	Al	*4*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Feature located on space-facing component.
2 - Spalled black thermal control paint from back surface.
3 - Two features within frame of image; two diameters separated by comma.
4 - Feature located on Row 9-facing strip.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration - KSC-390C-3416.06 and KSC-390C-3416.07
M&D SIG Photos - S90-43593 - Feature #23 back surface bulge and paint spall.

ARCHIVED MATERIALS:

Thermal Panel Reflector - H22R01

LDEF LOCATION: H23
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W. M. BERRIOS
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HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel H23 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (space-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 10-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the space-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 10-facing direction. Panel H23 was attached to the spacecraft by eighteen 303 stainless steel bolts (nine on the space-facing side and nine on the Row 10-facing strip). An ~3" in diameter amber reflector was attached to a 0.062" (1.6 mm) thick, chromic-anodized aluminum plate which in turn, was attached to the thermal panel at bolt locations H23S01N and H23S01M on the Row 10-facing strip.

Detailed examination of Thermal Panel H23 by the M&D SIG A-Team visually identified 158 impact features. One hundred thirty one of these impacts were <0.5 mm in diameter; 69 of these were on the space-facing component, 59 were on the Row 10-facing strip, and three were on the reflector. Twenty three impact features were between 0.5 mm and 1.0 mm in diameter; six of these were on the space-facing component, 16 were on the Row 10-facing strip, and one was on the reflector. Four of the impact features were between 1.0 mm and 1.5 mm in diameter; one of these was on the space-facing component and the other three were on the Row 10 facing strip. None of the highly-oblique features observed by the M&D SIG A-Team on the Earth-end thermal panels were discovered on the space-end thermal panels while at Kennedy Space Center. A more detailed, microscopic examination of the space-end thermal panels is being conducted at Langley Research Center in search of highly-oblique features. Morphologically, all features examined on this thermal control panel were typical of craters produced in aluminum during controlled laboratory hypervelocity impact tests.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 10-FACING STRIP	SPACE-FACING COMPONENT	TOTALS
<0.5 mm	3	59	69	131
>0.5 mm	1	19	7	27
TOTALS	4	78	76	158

The largest impact features identified were (1) an ~1.0 mm diameter crater located on the space-facing component surface, (2) an ~1.2 mm diameter crater in the Row 10-facing strip, and (3) an ~ 0.6 mm crater on the reflector which was mounted to the Row 10-facing strip.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel H23 was conducted on March 29, 1990 and identified one feature near bolt H23F which might be damaged by removal of the panel from the spacecraft. A request for Ground Operations personnel to use special care in the removal of this bolt was made by the M&D SIG A-Team.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the 0.0625" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

The detailed examination and photodocumentation of Thermal Control Panel H23 was conducted on April 20, 1990. The space-facing component of the panel was examined and photodocumented in the horizontal position, and the Row 10-facing strip was examined and photodocumented in the vertical position. Both components were scanned and imaged using M&D SIG System #2. The coordinates of features were measured using M&D SIG Coordinate Registration System #3. The bolts and reflector associated with this tray were also scanned and imaged with M&D SIG System #2; the coordinates for features residing on the reflector were measured with a metric scale. The (0,0) reference point for all space-end thermal panels was at the lower left-hand corner of the panel at the intersection of the space-facing and row-facing surfaces (Figure H23-1). All features photodocumented on the various row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the space-facing component to the location of the feature on the row-facing strip.

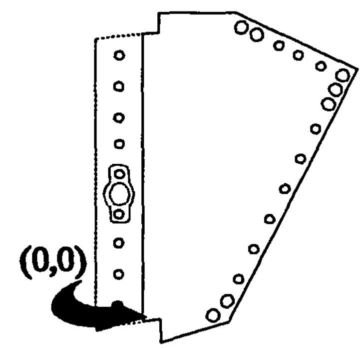

Figure H23-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel H23.

Impact Features Imaged on Exposed Thermal Panel and Reflector Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.H23	RE000001.H23	103	124		1.0	Al	*1*
LE000002.H23	RE000002.H23	80	239		0.7	Al	*1,d*
LE000003.H23	RE000003.H23	34	993		0.9	Al	*1*
LE000004.H23	RE000004.H23	175	912		0.6	Al	*1*
LE000005.H23	RE000005.H23	311	649		0.5	Al	*1*
LE000006.H23	RE000006.H23	78	905		0.5	Al	*1*
LE000007.H23	RE000007.H23	14	901		0.5	Al	*1*
LE000008.H23	RE000008.H23	0	127	12	0.9	Al	*2*
LE000009.H23	RE000009.H23	0	105	76	0.9	Al	*2*
LE000010.H23	RE000010.H23	0	270	88	0.8	Al	*2*
LE000011.H23	RE000011.H23	0	325	17	0.8	Al	*2*
LE000012.H23	RE000012.H23	0	234	23	0.5	Al	*2*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000013.H23	RE000013.H23	0	170	98	0.6	Al	*2*
LE000014.H23	RE000014.H23	0	17	92	0.5	Al	*2*
LE000015.H23	RE000015.H23	0	310	13	0.5	Al	*2*
LE000016.H23	RE000016.H23	0	324	73	0.6	Al	*2*
LE000017.H23	RE000017.H23	0	46	52	0.6	Al	*2*
AE000018.H23	BE000018.H23	0	475	21	1.2	Al	*2,5*
LE000019.H23	RE000019.H23	0	486	50	0.6	Al	*2*
LE000020.H23	RE000020.H23	0	681	50	0.8	Al	*2*
LE000021.H23	RE000021.H23	0	732	8	1.0	Al	*2*
LE000022.H23	RE000022.H23	0	721	45	0.5	Al	*2,3*
LE000023.H23	RE000023.H23	0	750	154	0.8	Al	*2*
LE000024.H23	RE000024.H23	0	908	67	1.0	Al	*2*
CE000025.H23	DE000025.H23	0	729	108	0.8	Al	*2,5*
LE000026.H23	RE000026.H23	0	745	153	0.6	Al	*2*
LR230001.H23	RR230001.H23	112	-8		0.6	Al	*4*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Feature located on space-facing component.
2 - Feature located on Row 10-facing strip.
3 - Wrong coordinates (X = 729, Z = 108) input into image file.
4 - Feature located on aluminum plate supporting reflector.
5 - Prior images bad due to computer failure.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration - KSC-390C-3417.11, KSC-390C-3413.09, and 3413.10
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION: H24
EXPERIMENT TITLE: THERMAL CONTROL PANEL
PRINCIPAL INVESTIGATOR: W.M. BERRIOS
434 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

A total of twenty four Thermal Control Panels were flown on LDEF; twelve each on the Earth- and space-facing ends of the spacecraft. All panels were manufactured from 0.062" (1.6 mm) thick, anodized aluminum sheets with the Earth- and space-end thermal panels differing only in the anodization process which was applied to the aluminum. The space-end thermal panels received the standard, chromic anodization process which was applied to the majority of the LDEF hardware, while the Earth-end thermal panels received a slightly different process which is of a proprietary nature. The black anodized, Earth-end thermal panels possessed an Adsorption/Emissivity (A/E) property of ~10, while the A/E property of their clear chromic-anodizied, space-end counterparts ranged from ~0.5 to 3. An approximately 6" (15.2 cm) strip of each thermal panel wrapped around the end of the spacecraft exposing a portion of its total surface area in the direction of the Row (1-12) to which it was adjacent.

Panel H24 was one of eight approximately triangular-shaped thermal panels adjacent to Rows 1, 2, 4, 5, 7, 8, 10, and 11, respectively (space-facing component measuring ~23.6" x 36.4" x 42.5" [~60 x 92.5 x 108 cm], while the Row 11-facing strip measured ~6.25" x 38.9" [~15.9 x 98.8 cm]). The total exposed surface area of the triangular-shaped thermal panels was ~675 in^2 (~4354 cm^2), approximately 430 in^2 (~2,775 cm^2) of which was in the space-facing direction and ~245 in^2 (~1,579 cm^2) of which was in the Row 11-facing direction. Panel H24 was attached to the spacecraft by eighteen 303 stainless steel bolts (nine on the space-facing side and nine on the Row 11-facing strip).

Detailed examination of Thermal Panel H24 revealed 133 features, 116 of which were <0.5 mm in diameter and were not photodocumented (64 on the space-facing component and 52 on the Row 11-facing strip). Of the 17 remaining impacts 11 resided on the space-facing component and ranged in size from 0.6 mm to 1.6 mm the latter being the largest impact found on the space-facing component of thermal panel H24. The six imaged impacts residing on the Row 11-facing strip ranged in diameter from 0.5 mm to 1.7 mm with the latter being the largest impact found on thermal panel H24. None of the highly-oblique features observed by the M&D SIG A-Team on the various Earth-end thermal panels were discovered on the space-end thermal panels while at KSC. A more detailed, microscopic examination of the space-end thermal panels is being conducted at LaRC in search of highly-oblique features. Morphologically, the craters examined on this thermal-control panel were typical of impact craters formed in similar material under controlled, laboratory conditions.

FEATURE SUMMARY

	BOLTS & REFLECTOR	ROW 11-FACING STRIP	SPACE-FACING COMPONENT	TOTALS
<0.5 mm		52	64	116
>0.5 mm		6	11	17
TOTALS		58	75	133

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The on-spacecraft inspection of Thermal Panel H24 was conducted on March 29, 1990 and revealed two features near bolts H24S01G and H24S01J (on the space-facing component and on Row 11-facing strip,

respectively) of the thermal panel that might be damaged by the removal of the panel from the spacecraft. A request for Ground Operations personnel to use special care in the removal of this bolt was made by the M&D SIG.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations bulges, or spallation features on the 0.062" (1.6 mm) thick thermal control panel.

DOCUMENTATION:

Examination and photodocumentation of Thermal Panel H24 was conducted on April 16, 1990. Both the space-facing component and the Row 11-facing strip were photodocumented (in the horizontal and vertical mode, respectively) using M&D SIG System #2 and the coordinates were documented using Coordinate Registration System #3. The bolts and reflector associated with this thermal panel were scanned with M&D SIG System #1. The (0,0) reference point for all space-end thermal panels was at the low left-hand corner of the panel at the intersection of the space-facing and row-facing surfaces (Figure H24-1). All features photodocumented on the carious row-facing strips were assigned positive Z values, with Z representing the distance from the surface of the space-facing component to the location of the feature on the row-facing strip.

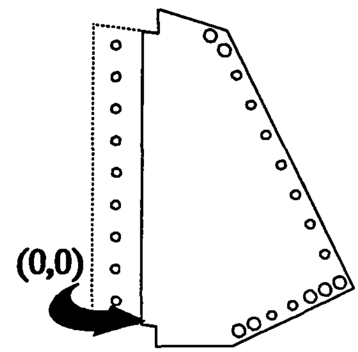

Figure H24-1. Diagram indicating the position of the (0,0) reference point for Thermal Panel H24.

Impact Features Imaged on Exposed Thermal Panel Surface

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.H24	RE000001.H24	129	319		0.7	Al	*1*
LE000002.H24	RE000002.H24	124	420		0.7	Al	*1*
LE000003.H24	RE000003.H24	127	525		1.2	Al	*1*
LE000004.H24	RE000004.H24	82	656		0.6	Al	*1*
LE000005.H24	RE000005.H24	116	878		0.7	Al	*1*
LE000006.H24	RE000006.H24	331	526		1.6	Al	*1*
LE000007.H24	RE000007.H24	411	444		1.3	Al	*1*
LE000008.H24	RE000008.H24	403	309		0.7	Al	*1*
LE000009.H24	RE000009.H24	250	90		0.6	Al	*1*
LE000010.H24	RE000010.H24	285	65		0.7	Al	*1*
LE000011.H24	RE000011.H24	295	310		0.6	Al	*1*
LE000012.H24	RE000012.H24	0	678	22	1.7	Al	*2,d*
LE000013.H24	RE000013.H24	0	726	155	0.7	Al	*2*
LE000014.H24	RE000014.H24	0	987	140	0.7	Al	*2*
LE000015.H24	RE000015.H24	0	625	78	0.5	Al	*2*
LE000016.H24	RE000016.H24	0	650	134	0.5	Al	*2*
LE000017.H24	RE000017.H24	0	238	4	0.7	Al	*2,3*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Feature located on space-facing component of thermal panel.
2 - Feature located on Row 11-facing strip of thermal panel.
3 - Feature located on curve of thermal panel.
4 - Doublet impact feature.
5 - Photo taken at 12X to show debris spray.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-deintegration
Post Deintegration - KSC-390C-3413.06 and KSC-390C-3413.07
M&D SIG Photos - None

ARCHIVED MATERIALS:

Thermal Panel Bolts - None

LDEF LOCATION: A03
EXPERIMENT TITLE: SCUFF PLATE, WALKING BEAM
PRINCIPAL INVESTIGATOR: LDEF PROJECT OFFICE
NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Scuff Plate A03 is one of four scuff plates on LDEF whose purpose were to provide a degree of protection to the experiment trays located in the vicinity of the walking-beam and center-ring trunnion pins (*i.e.*, near A03 and A09, and C03 and C09, respectively) during handling, moving, launching, and retrieval of the LDEF spacecraft; the keel trunnion pin (C06) did not possess a scuff plate. Each scuff plate was constructed from ~0.375" (8.9 mm) thick, 6061-T6 aluminum which tapered to a thickness of ~0.25" (6.4 mm) at the edge, and were attached to LDEF by four 303 stainless steel bolts. All were semi-circular in shape and ~19" (48.3 cm) in diameter, not including the additional ~4" (10.2 cm) wide skirt which projected at an ~45° angle from the slightly hemispherical, semi-circular main face of the scuff plate. Prior to launch, all four scuff plates were painted with two or three layers of a space-approved, bright yellow thermal-control paint. However, following retrieval the two trailing-edge scuff plates (A03 and C03) were a dull brown to olive-green color, while the two leading-edge scuff plates (A09 and C09) had retained their original bright yellow appearance. Scuff Plate A03 was located on the walking-beam trunnion pin which protruded beyond the spacecraft near Bay A03 on the Earth-end of LDEF.

The M&D SIG survey of Scuff Plate A03 identified and photodocumented seven impact features on all scuff-plate surfaces, three of which were located on the hemispherical main face, and four which were located on the ~4" (10.2 cm) shirt. Unfortunately, the diameters of these features were not estimated and recorded in the logbook, or with the acquired image files. The diameters of these features will be known only after the stereo pairs are combined, and the resulting 3-D images analyzed. Morphologically, all features examined were typical of craters produced in painted aluminum surfaces under controlled laboratory conditions (*i.e.*, craters were generally surrounded by front-surface spall zones in the paint layers). As the paint was in several layers on these scuff plates, it was not unusual to find the diameter of the associated spall zone to vary from layer to layer.

FEATURE SUMMARY

	SKIRT AREA	SCUFF PLATE FACE	TOTALS
<0.5 mm			@
>0.5 mm			
TOTALS	4	3	7

@ - The survey for "Too Smalls" was not conducted.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The M&D SIG A-Team was not provide an opportunity to examine the A03 scuff plate prior to its removal from the spacecraft. However, there was no apparent damage to any of the impact features noted when its was examined.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the A03 scuff plate.

DOCUMENTATION:

The detailed examination of Scuff Plate A03 was conducted on February 4, 1990 in the horizontal position utilizing M&D SIG System #1; coordinates for photodocumented features were determined with a metric scale. The (0,0) reference point for this scuff plate was at the upper left-hand corner, where the hemispherical main face intersected the skirt area. X-coordinates were measured around the circumference of the plate along the line formed by the this intersection. Features residing on the hemispherical main face were assigned positive Y-values, with the value equaling the distance (measured radially toward the hole in the center of the scuff plate) to the feature from this intersection line. Correspondingly, negative Y-values were assigned to all features residing on the skirt area, with the negative Y-value equaling the distance to the feature from the main face- and skirt-area intersection line (Figure SP-A03-1). All imaged features were stored with the wrong component designation (*i.e.*, G02 instead of T02).

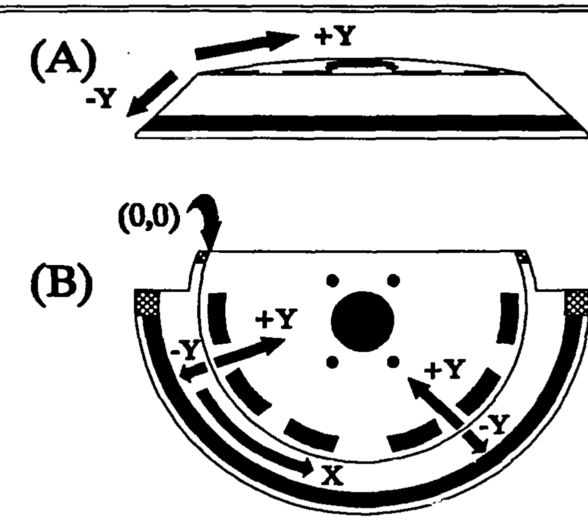

Figure SP-A03-1. Diagram illustrating the location of the (0,0) reference point and the technique in which X- and Y-coordinates were determined.

Impact Features Imaged on Exposed Scuff Plate Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LG020001.A03	RG020001.A03	130	31		ND	Al (painted)	*b*
LG020002.A03	RG020002.A03	400	19		ND	Al (painted)	*1,b*
AG020002.A03	BG020002.A03	400	19		ND	Al (painted)	*1,2,b*
LG020003.A03	RG020003.A03	465	154		ND	Al (painted)	*b*
LG020004.A03	RG020004.A03	730	-13		ND	Al (painted)	*b*
AG020004.A03	BG020004.A03	730	-13		ND	Al (painted)	*2,b*
LG020005.A03	RG020005.A03	560	-70		ND	Al (painted)	*b*
LG020006.A03	RG020006.A03	340	-97		ND	Al (painted)	*3,b*
LG020007.A03	RG020007.A03	305	-22		ND	Al (painted)	*4,b*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Impact into black-painted area on front face.
2 - Higher magnification view of feature LG020002.A03.
3 - Spall zone present, but little or no penetration into aluminum substrate.
4 - Crater in aluminum substrate not centered in associated spall zone.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration
M&D SIG Photos - None

ARCHIVED MATERIALS:

None

LDEF LOCATION: A09
EXPERIMENT TITLE: SCUFF PLATE, WALKING BEAM
PRINCIPAL INVESTIGATOR: LDEF PROJECT OFFICE
NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Scuff Plate A09 is one of four scuff plates on LDEF whose purpose were to provide a degree of protection to the experiment trays located in the vicinity of the walking-beam and center-ring trunnion pins (*i.e.*, near A03 and A09, and C03 and C09, respectively) during handling, moving, launching, and retrieval of the LDEF spacecraft; the keel trunnion pin (C06) did not possess a scuff plate. Each scuff plate was constructed from ~0.375" (8.9 mm) thick, 6061-T6 aluminum which tapered to a thickness of ~0.25" (6.4 mm) at the edge, and were attached to LDEF by four 303 stainless steel bolts. All were semi-circular in shape and ~19" (48.3 cm) in diameter, not including the additional ~4" (10.2 cm) wide skirt which projected at an ~45° angle from the slightly hemispherical, semi-circular main face of the scuff plate. Prior to launch, all four scuff plates were painted with two or three layers of a space-approved, bright yellow thermal-control paint. However, following retrieval the two trailing-edge scuff plates (A03 and C03) were a dull brown to olive-green color, while the two leading-edge scuff plates (A09 and C09) had retained their original bright yellow appearance. Scuff Plate A09 was located on the walking-beam trunnion pin which protruded beyond the spacecraft near Bay A09 on the Earth-end of LDEF.

The M&D SIG survey of Scuff Plate A09 identified and photodocumented 31 impact features on all scuff-plate surfaces, 20 of which were located on the hemispherical main face, and 11 which were located on the ~4" (10.2 cm) shirt. Unfortunately, the diameters of these features were not estimated and recorded in the logbook, or with the acquired image files (except for features LG010001.A09 and LG0100031.A09 which measured ~1.0 mm and ~1.4 mm in diameter, respectively). The diameters for the remaining 29 features will be known only after the stereo pairs are combined, and the resulting 3-D images analyzed. Morphologically, all features examined were typical of craters produced in painted aluminum surfaces under controlled laboratory conditions (*i.e.*, craters were generally surrounded by front-surface spall zones in the paint layers). As the paint was in several layers on these scuff plates, it was not unusual to find the diameter of the associated spall zone to vary from layer to layer.

FEATURE SUMMARY

	SKIRT AREA	SCUFF PLATE FACE	TOTALS
<0.5 mm			@
>0.5 mm			
TOTALS	11	20	31

@ - The survey for "Too Smalls" was not conducted.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The M&D SIG A-Team was not provide an opportunity to examine the A09 scuff plate prior to its removal from the spacecraft. However, there was no apparent damage to any of the impact features noted when its was examined.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the A09 scuff plate.

DOCUMENTATION:

The detailed examination of Scuff Plate A09 was conducted on February 4, 1990 in the horizontal position utilizing M&D SIG System #3; coordinates for photodocumented features were determined with a metric scale. The (0,0) reference point for this scuff plate was at the upper left-hand corner, where the hemispherical main face intersected the skirt area. The X-coordinates of features were measured form the (0,0) reference point along ~19" (48.3 cm) diameter of the scuff plate in a normal Cartesian-grid fashion. Features residing on the hemispherical main face were assigned positive Y-values, with the value equaling the distance (measured radially toward the hole in the center of the scuff plate) to the feature from the line formed by the intersection of the hemispherical main face and the skirt area. Correspondingly, negative Y-values were assigned to all features residing on the skirt area, with the negative Y-value equaling the distance to the feature from the main face- and skirt area intersection line (Figure SP-A09-1). All imaged features were stored with the wrong component designation (*i.e.*, G01 instead of T01).

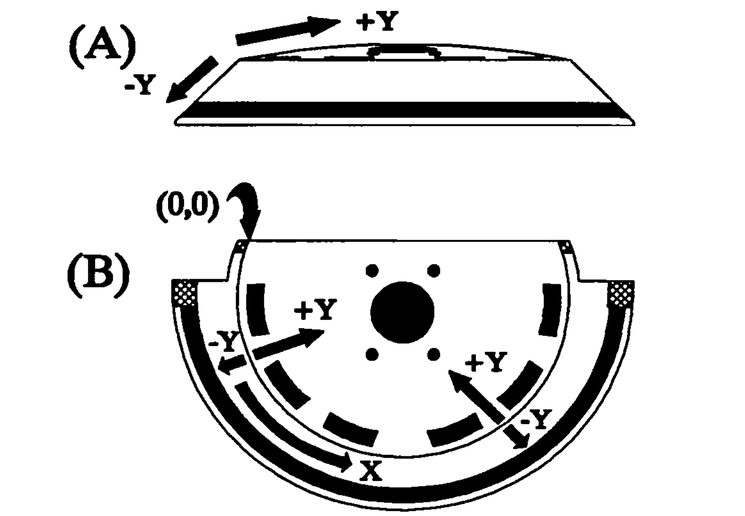

Figure SP-A09-1. Diagram illustrating the location of the (0,0) reference point and the technique in which X- and Y-coordinates were determined.

Impact Features Imaged on Scuff Plate Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LG010001.A09	RG010001.A09	30	32		1.0	Al (painted)	1
AG010001.A09	BG010001.A09	30	32		ND	Al (painted)	1
LG010002.A09	RG010002.A09	35	64		ND	Al (painted)	2
LG010003.A09	RG010003.A09	32	96		ND	Al (painted)	
LG010004.A09	RG010004.A09	49	163		ND	Al (painted)	
LG010005.A09	RG010005.A09	96	120		ND	Al (painted)	
LG010006.A09	RG010006.A09	110	105		ND	Al (painted)	
AG010006.A09	BG010006.A09	110	105		ND	Al (painted)	
LG010007.A09	RG010007.A09	114	110		ND	Al (painted)	
LG010008.A09	RG010008.A09	155	85		ND	Al (painted)	
LG010009.A09	RG010009.A09	150	68		ND	Al (painted)	3
LG010010.A09	RG010010.A09	192	45		ND	Al (painted)	
LG010011.A09	RG010011.A09	199	51		ND	Al (painted)	
LG010012.A09	RG010012.A09	203	98		ND	Al (painted)	
LG010013.A09	RG010013.A09	245	65		ND	Al (painted)	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LG010014.A09	RG010014.A09	243	82		ND	Al (painted)	
LG010015.A09	RG010015.A09	232	93		ND	Al (painted)	
LG010016.A09	RG010016.A09	299	34		ND	Al (painted)	
LG010017.A09	RG010017.A09	182	172		ND	Al (painted)	
LG010018.A09	RG010018.A09	480	50		ND	Al (painted)	*6*
LG010019.A09	RG010019.A09	586	65		ND	Al (painted)	*6*
LG010020.A09	RG010020.A09	578	16		ND	Al (painted)	*6*
LG010021.A09	RG010021.A09	78	-6		ND	Al (painted)	*5*
LG010022.A09	RG010022.A09	150	-25		ND	Al (painted)	*5*
LG010023.A09	RG010023.A09	180	-7		ND	Al (painted)	*5*
LG010024.A09	RG010024.A09	325	-12		ND	Al (painted)	*5*
LG010025.A09	RG010025.A09	365	-70		ND	Al (painted)	*5*
LG010026.A09	RG010026.A09	372	-80		ND	Al (painted)	*5*
LG010027.A09	RG010027.A09	396	-90		ND	Al (painted)	*5*
LG010028.A09	RG010028.A09	485	-90		ND	Al (painted)	*5,6*
LG010029.A09	RG010029.A09	496	-42		ND	Al (painted)	*5,6*
LG010030.A09	RG010030.A09	557	-38		ND	Al (painted)	*5,6*
LG010031.A09	RG010031.A09	688	-95		1.4	Al (painted)	*4,5,6*
AG010031.A09	BG010031.A09	688	-95		1.4	Al (painted)	*4,5,6*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

ND - Not Determined

1 - Spall zone associated with crater. Machine lines visible in aluminum surface below paint.
2 - Large double spall around crater.
3 - Doublet feature.
4 - Largest feature on scuff plate.
5 - Wrong Y-coordinate stored with image file, all values were negative.
6 - Wrong X-coordinate stored with image file.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-deintegration
Post Deintegration
M&D SIG Photos - None

ARCHIVED MATERIALS:

None

LDEF LOCATION:	**C03**
EXPERIMENT TITLE:	**SCUFF PLATE, CENTER RING**
PRINCIPAL INVESTIGATOR:	**LDEF PROJECT OFFICE**
	NASA LANGLEY RESEARCH CENTER
	HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

Scuff Plate C03 is one of four scuff plates on LDEF whose purpose were to provide a degree of protection to the experiment trays located in the vicinity of the walking-beam and center-ring trunnion pins (*i.e.*, near A03 and A09, and C03 and C09, respectively) during handling, moving, launching, and retrieval of the LDEF spacecraft; the keel trunnion pin (C06) did not possess a scuff plate. Each scuff plate was constructed from ~0.375" (8.9 mm) thick, 6061-T6 aluminum which tapered to a thickness of ~0.25" (6.4 mm) at the edge, and were attached to LDEF by four 303 stainless steel bolts. All were semi-circular in shape and ~19" (48.3 cm) in diameter, not including the additional ~4" (10.2 cm) wide skirt which projected at an ~45° angle from the slightly hemispherical, semi-circular main face of the scuff plate. Prior to launch, all four scuff plates were painted with two or three layers of a space-approved, bright yellow thermal-control paint. However, following retrieval the two trailing-edge scuff plates (A03 and C03) were a dull brown to olive-green color, while the two leading-edge scuff plates (A09 and C09) had retained their original bright yellow appearance. Scuff Plate C03 was located on the center-ring trunnion pin between Bays C03 and D03.

The M&D SIG survey of Scuff Plate C03 identified and photodocumented seven impact features <0.5 mm in diameter on all scuff-plate surfaces, four of which were located on the hemispherical main face, and three which were located on the ~4" (10.2 cm) shirt. One additional feature on the skirt area of this scuff plate was identified, but not photodocumented. Morphologically, all features examined were typical of craters produced in painted aluminum surfaces under controlled laboratory conditions (*i.e.*, craters were generally surrounded by front-surface spall zones in the paint layers). As the paint was in several layers on these scuff plates, it was not unusual to find the diameter of the associated spall zone to vary from layer to layer.

FEATURE SUMMARY

	SKIRT AREA	SCUFF PLATE FACE	TOTALS
<0.5 mm	4	4	8@
>0.5 mm			
TOTALS	4	4	8

@ - The survey for "Too Smalls" was not conducted.

The largest impact feature identified on Scuff Plate C03 was an ~0.4 mm in diameter feature located on the hemispherical main face.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The M&D SIG A-Team was not provided an opportunity to examine the C03 scuff plate prior to its removal from the spacecraft. However, there was no apparent damage to any of the impact features noted when its was examined.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the C03 scuff plate.

DOCUMENTATION:

The detailed examination of Scuff Plate C03 was conducted on February 20, 1990 in the horizontal position utilizing M&D SIG System #3; coordinates for photodocumented features were determined with a metric scale. The (0,0) reference point for this scuff plate was at the upper left-hand corner, where the hemispherical main face intersected the skirt area. The X-coordinates of features were measured form the (0,0) reference point along ~19" (48.3 cm) diameter of the scuff plate in a normal Cartesian-grid fashion. Features residing on the hemispherical main face were assigned positive Y-values, with the value equaling the distance (measured radially toward the hole in the center of the scuff plate) to the feature from the line formed by the intersection of the hemispherical main face and the skirt area. Correspondingly, negative Y-values were assigned to all features residing on the skirt area, with the negative Y-value equaling the distance to the feature from the main face- and skirt area intersection line (Figure SP-C03-1.).

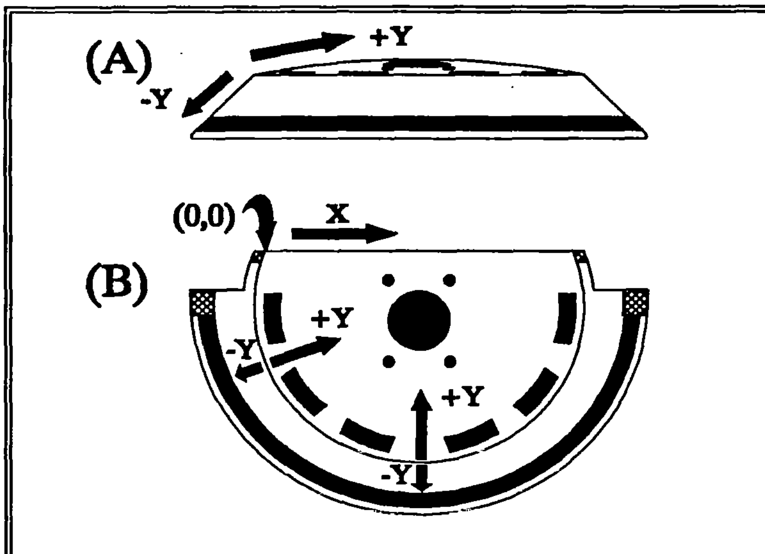

Figure SP-C03-1. Diagram illustrating the location of the (0,0) reference point and the technique in which X- and Y-coordinates were determined.

Impact Features Imaged on Scuff Plate Surfaces

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LT010001.C03	RT010001.C03	125	40		0.2	Al (painted)	*1*
LT010002.C03	RT010002.C03	248	95		0.2	Al (painted)	*2*
LT010003.C03	RT010003.C03	278	59		0.2	Al (painted)	*3,5*
LT010004.C03	RT010004.C03	354	124		0.2	Al (painted)	*4*
LT010005.C03	RT010005.C03	500	-14		0.3	Al (painted)	*6*
LT010006.C03	RT010006.C03	480	-87		0.4	Al (painted)	*5,7*
LT010007.C03	RT010007.C03	125	-55		0.3	Al (painted)	*6*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Diameter of spall zone is different in successive paint layers; D_2=0.8 mm and D_3=1.1 mm.
2 - Spall zone D_2=0.8 mm.
3 - Spall zone D_2=0.7 mm.
4 - Diameter of spall zone is different in successive paint layers; D_2=0.6 mm and D_3=0.8 mm.

5 - Irregular-shaped feature.
6 - Irregular-shaped spall zone.
7 - Wrong coordinates (X = 48, Y = -87) input into image file.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-deintegration
Post Deintegration
M&D SIG Photos - None

ARCHIVED MATERIALS:

None

LDEF LOCATION:	**C09**
EXPERIMENT TITLE:	**SCUFF PLATE, CENTER RING**
PRINCIPAL INVESTIGATOR:	**LDEF PROJECT OFFICE** **NASA LANGLEY RESEARCH CENTER** **HAMPTON, VIRGINIA 23665**

SUMMARY OF OBSERVATIONS

Scuff Plate C09 is one of four scuff plates on LDEF whose purpose were to provide a degree of protection to the experiment trays located in the vicinity of the walking-beam and center-ring trunnion pins (*i.e.*, near A03 and A09, and C03 and C09, respectively) during handling, moving, launching, and retrieval of the LDEF spacecraft; the keel trunnion pin (C06) did not possess a scuff plate. Each scuff plate was constructed from ~0.375" (8.9 mm) thick, 6061-T6 aluminum which tapered to a thickness of ~0.25" (6.4 mm) at the edge, and were attached to LDEF by four 303 stainless steel bolts. All were semi-circular in shape and ~19" (48.3 cm) in diameter, not including the additional ~4" (10.2 cm) wide skirt which projected at an ~45° angle from the slightly hemispherical, semi-circular main face of the scuff plate. Prior to launch, all four scuff plates were painted with two or three layers of a space-approved, bright yellow thermal-control paint. However, following retrieval the two trailing-edge scuff plates (A03 and C03) were a dull brown to olive-green color, while the two leading-edge scuff plates (A09 and C09) had retained their original bright yellow appearance. Scuff Plate C09 was located on the center-ring trunnion pin between Bays C09 and D09.

The M&D SIG survey of Scuff Plate C09 identified 68 features on all scuff-plate surfaces, 47 of which were located on the hemispherical main face, and 21 which were located on the ~4" (10.2 cm) shirt. Forty three of the 68 features were not photodocumented because they were <0.5 mm in diameter (27 on the hemispherical main face of the scuff plate and 16 on the skirt area). Of the remaining 25 features which were photodocumented, all but five were located on the hemispherical main face of the scuff plate (six of which were between 0.4 and 0.7 mm in diameter and 14 which were <0.4 mm in diameter). The five features on the skirt area ranged in size from ~0.3 mm to ~1.0 mm in diameter. Several features on both portions of the scuff plate were slightly elliptical in shape. Morphologically, all features examined were typical of craters produced in painted aluminum surfaces under controlled laboratory conditions (*i.e.*, craters were generally surrounded by front-surface spall zones in the paint layers). As the paint was in several layers on these scuff plates, it was not unusual to find the diameter of the associated spall zone to vary from layer to layer.

FEATURE SUMMARY

	SKIRT AREA	SCUFF PLATE FACE	TOTALS
<0.5 mm	17	44	61@
>0.5 mm	4	3	7
TOTALS	21	47	68

@ - The survey for "Too Smalls" was not conducted.

The largest features identified on Scuff Plate C09 were (1) an ~1.0 mm diameter feature and (2) an elliptical feature measuring ~0.5 x 0.7 mm, both of which were on the skirt area of the scuff plate. The largest spall zone area measured ~2.2 mm in diameter and was associated with an ~0.4 mm diameter crater.

M&D SIG INSPECTIONS

PRE-DEINTEGRATION:

The M&D SIG A-Team was not provide an opportunity to examine the C09 scuff plate prior to its removal from the spacecraft. However, there was no apparent damage to any of the impact features noted when its was examined.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the front or back of the C09 scuff plate.

DOCUMENTATION:

The detailed examination of Scuff Plate C09 was conducted on February 20, 1990 in the horizontal position utilizing M&D SIG System #3; coordinates for photodocumented features were determined with a metric scale. The (0,0) reference point for this scuff plate was at the upper left-hand corner, where the hemispherical main face intersected the skirt area. The X-coordinates of features were measured form the (0,0) reference point along ~19" (48.3 cm) diameter of the scuff plate in a normal Cartesian-grid fashion. Features residing on the hemispherical main face were assigned positive Y-values, with the value equaling the distance (measured radially toward the hole in the center of the scuff plate) to the feature from the line formed by the intersection of the hemispherical main face and the skirt area. Correspondingly, negative Y-values were assigned to all features residing on the skirt area, with the negative Y-value equaling the distance to the feature from the main face- and skirt area intersection line (Figure SP-C09-1).

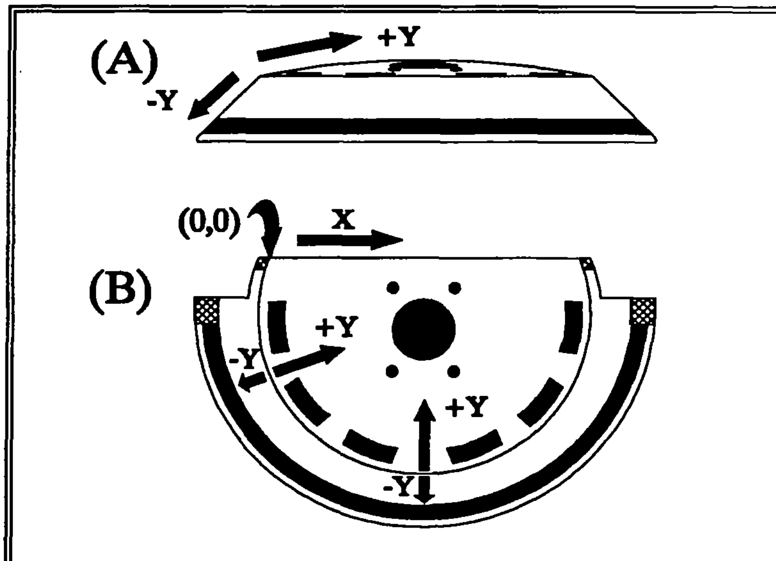

Figure SP-C09-1. Diagram illustrating the location of the (0,0) reference point and the technique in which X- and Y-coordinates were determined.

Impact Features Imaged on Scuff Plate Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LT010001.C09	RT010001.C09	555	-82		0.3	Al (painted)	*b*
LT010002.C09	RT010002.C09	540	-58		0.5	Al (painted)	*b*
LT010003.C09	RT010003.C09	370	-46		1.0	Al (painted)	
LT010004.C09	RT010004.C09	-48	-33		0.5 x 0.7	Al (painted)	
LT010005.C09	RT010005.0C9	-80	-71		0.6	Al (painted)	
LT010006.C09	RT010006.C09	37	35		0.3	Al (painted)	*b*
LT010007.C09	RT010007.C09	-15	8		0.6	Al (painted)	*1,b*
LT010008.C09	RT010008.C09	-15	8		0.6	Al (painted)	*2,b*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LT010009.C09	RT010009.C09	56	46		0.4	Al (painted)	*1,b*
AT010009.C09	BT010009.C09	56	46		0.4	Al (painted)	*b*
LT010010.C09	RT010010.C09	111	135		0.3	Al (painted)	*1,b*
AT010010.C09	BT010010.C09	111	135		0.3	Al (painted)	*b*
LT010011.C09	RT010011.C09	122	145		0.3	Al (painted)	*1,b*
AT010011.C09	BT010011.C09	122	145		0.3	Al (painted)	*b*
LT010012.C09	RT010012.C09	148	152		0.4	Al (painted)	*1,b*
AT010012.C09	BT010012.C09	148	152		0.4	Al (painted)	*b*
LT010013.C09	RT010013.C09	110	40		0.3 x 0.4	Al (painted)	*1,b*
AT010013.C09	BT010013.C09	110	40		0.3 x 0.4	Al (painted)	*b*
LT010014.C09	RT010014.C09	284	44		0.4	Al (painted)	*3*
LT010015.C09	RT010015.C09	315	44		0.4 x 0.6	Al (painted)	
LT010016.C09	RT010016.C09	345	37		0.4	Al (painted)	*1,b*
AT010016.C09	BT010016.C09	345	37		0.4	Al (painted)	*b*
LT010017.C09	RT010017.C09	250	95		0.3	Al (painted)	*k*
LT010018.C09	RT010018.C09	298	84		0.3	Al (painted)	*4,b*
LT010019.C09	RT010019.C09	460	16		0.4	Al (painted)	*b*
LT010020.C09	RT010020.C09	464	13		0.2	Al (painted)	*b*
LT010021.C09	RT010021.C09	343	131		0.4	Al (painted)	
LT010022.C09	RT010022.C09	361	110		0.4	Al (painted)	
LT010023.C09	RT010023.C09	420	78		0.3	Al (painted)	*5*
LT010024.C09	RT010024.C09	418	39		0.2 x 0.3	Al (painted)	*4,b*
LT010025.C09	RT010025.C09	460	40		0.3	Al (painted)	*3,4,b*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Higher magnification view.
2 - Low magnification view of feature LT010007.C09.
3 - Incorrect coordinates (X = 315, Y = 44) entered with image file.
4 - Multiple front surface spall zones surrounding impact feature.
5 - Second feature (~0.1 mm in diameter) in field of view.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration - KSC-390C-1030.12, KSC-390C-1031.01, KSC-390C-1031.02, KSC-390C-1031.08, KSC-390C-1031.09
Post Deintegration - S90-01524, S90-01534, S90-01538
M&D SIG Photos - None

ARCHIVED MATERIALS:

None

LDEF LOCATION: BAY G
EXPERIMENT TITLE: WALKING BEAM
PRINCIPAL INVESTIGATOR: LDEF PROJECT OFFICE
NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

The Walking Beam (attached to the Earth-end) provided the principal load-bearing support for the launch and retrieval of the LDEF spacecraft. A trunnion pin, and its associated scuff plate, was attached to each end of this chromic-anodized aluminum structure. From tip to tip, including both stainless steel trunion pins, the Walking beam measured ~194.6" (494.4 cm) long and consisted of two upper and two lower, ~4" (10.2 cm) in diameter circular bars, with the lowers bars at an ~20° (toward Bay G06) with respect to the upper set. The central portion of the Walking Beam was occupied by a thick, hour glass-shaped flange, in which the upper and lower bars terminated toward the center of the spacecraft. A large hole (spindle hole) in the center of this flange served as the attachment point between the Walking Beam and LDEF, and was the location where the Walking-Beam removal fixture attached for its deintegration from the spacecraft. In space, this hole was covered by a chromic-anodized aluminum plate which was held in place by four 303 stainless steel bolts. On either end, the bars joined at the ~20° in an ~6" (15.2 cm) thick end-junction block; the aluminum trunnion-pin fixtures attached to the other side (outward facing) of this block (Figure WB-1). Two aluminum retaining clamps (located between Bay G03 and thermal-panel G16, and between Bay G09 and thermal-panel G22, respectively) served to prevent the Walking Beam from rotating around the central spindle-hole attachment point. Each of the retaining clamps were attached to the LDEF structure by two 303 stainless steel bolts.

The M&D SIG survey of the Walking Beam and its associated hardware identified a total of 35 impact features. Twenty five of the 35 features were <0.5 mm in diameter (two of which were located on the plate covering the spindle hole, two were located on the Row 3 trunnion-pin fixture, two were located on the retaining clamps [one on each], and 19 on the Walking Beam). Of the remaining ten features, nine were between 0.5 mm and 1.0 mm in diameter (eight on the Walking Beam [one of which was an elliptical feature measuring ~0.8 x 1.3 mm in size] and one on the spindle-hole cover plate), and one was ~1.3 mm in diameter and was located on the retaining clamp near Bay G03. No impact features were identified on any of the bolts associated with the Walking Beam. Morphologically, all features were typical of craters produced in aluminum under controlled laboratory conditions.

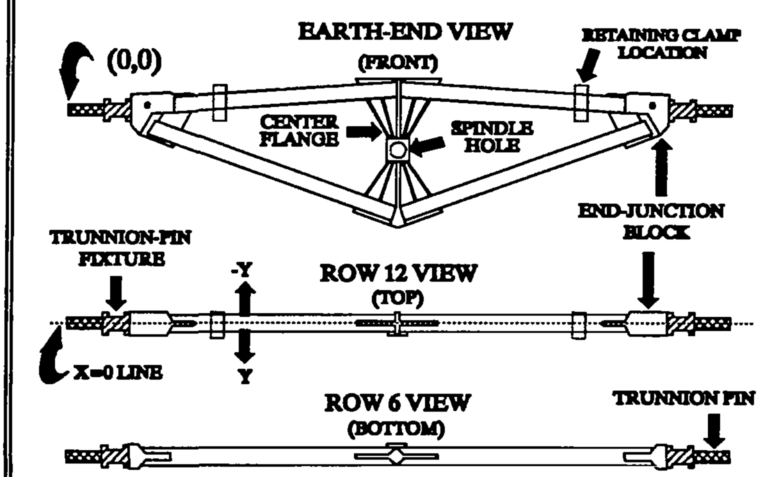

Figure WB-1. Diagram of the Walking Beam which was attached to the Earth-end of LDEF. The (0,0) reference point was at the end of the trunnion pin near Bay A09.

FEATURE SUMMARY

	SPINDLE-HOLE COVER PLATE	TRUNNION-PIN FIX./-RETAINING CLAMPS	WALKING BEAM	TOTALS
<0.5 mm	2	4	19	25
>0.5 mm	1	1	8	10
TOTALS	3	5	27	35

The largest impact features identified were (1) an ~0.8 x 1.3 mm elliptical feature on the Walking Beam, (2) an ~1.3 mm in diameter feature on the G03 retaining clamp, and (3) an ~0.5 mm in diameter feature in the spindle-hole cover plate.

M&D SIG INSPECTION

PRE-DEINTEGRATION:

The M&D SIG A-Team was not provide an opportunity to examine the Walking Beam prior to its removal from the spacecraft. However, there was no apparent damage to any of the impact features noted when its was examined.

GENERAL FRONT AND BACKSIDE:

There were no noticeable penetrations, bulges, or spallation features on the Walking Beam or its associated hardware.

DOCUMENTATION:

The detailed examination and photodocumentation of the Walking Beam was conducted on February 6, 1990 in the horizontal position utilizing M&D SIG System #3; coordinates for photodocumented features were determined with a metric tape measure. The (0,0) reference point for the Walking Beam was at the tip of the Row 9 trunnion pin on the Row 12-facing edge (tangent). X-coordinates were measured in a normal Cartesian-grid fashion along the Row 12-facing tangent, while Y-coordinates were measured radially around the bars/structure from the Row 12-facing tangent with positive Y-values being assigned to all features on the Earth-facing portions of the Walking Beam, Figure Wb-1). The spindle-hole cover plate, retaining clamps, trunnion-pin fixtures, and associated bolts were examined and photodocumented utilizing M&D SIG System #2. The coordinates for features residing on these miscellaneous pieces were measured with a small metric scale.

Impact Features Imaged on Exposed Surfaces

IMAGE FILE NAMES LEFT	IMAGE FILE NAMES RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LF010001.G25	RF010001.G25	0	-1		0.5	Al	*1*
LC010001.G03	RC010001.G03	6	3		1.3	Al	*2*
LB010001.G25	RB010001.G25	448	60		0.9	Al	*3*
LB010002.G25	RB010002.G25	618	57		0.8	Al	*3,4*
LB010003.G25	RB010003.G25	1793	82		0.8	Al	*3,5*
LB010004.G25	RB010004.G25	2542	75		0.5	Al	*3,6*
LB010005.G25	RB010005.G25	4575	110		0.3	Al	*3,6*
LB010006.G25	RB010006.G25	3428	-92		0.5	Al	*6,7*
LB010007.G25	RB010007.G25	2020	25		0.8 x 1.3	Al	*6,8,9,d,k*
AB010007.G25	BB010007.G25	2020	25		0.8 x 1.3	Al	*6,8,10,d,k*
CB010007.G25	DB010007.G25	2020	25		0.8 x 1.3	Al	*6,8,10,d,k*
EB010007.G25	FB010007.G25	2020	25		0.8 x 1.3	Al	*6,8,9,d,k*

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LB010008.G25	RB010008.G25	1532	-85		0.5	Al	*7*
LB010009.G25	RB010009.G25	880	-75		0.5	Al	*7*
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Feature on edge of sindle-hole cover plate.
2 - Feature on side of Row 3 trunnion-pin fixture.
3 - Feature on Row 12-facing edge of Walking Beam.
4 - Wrong X-coordinate (X = 691) input into image file.
5 - Wrong X-coordinate (X = 1866) input into image file.
6 - Wrong X-coordinate (X = 2000) input into image file.
7 - Feature on Row 6-facing edge of Walking Beam.
8 - Feature on Earth-facing edge of Walking Beam.
9 - Image taken at ~30° below the normal to the crater.
10 - Higher magnification view of feature.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration
M&D SIG Photos

ARCHIVED MATERIALS:

None

LDEF LOCATION: STRUCTURAL FRAME

PRINCIPAL INVESTIGATOR: LDEF PROJECT OFFICE
434 NASA LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

SUMMARY OF OBSERVATIONS

The frame of the ~30' x 14' (~9.1 x 4.3 m) LDEF spacecraft was constructed from chromic-anodized, 6061-T6 extruded aluminum beams (members) which had been painted black on all non-space exposed surfaces. Two main beam types were utilized in the construction of the LDEF frame (1) Longerons and (2) Intercostals. Longerons were the aluminum I-beams (~14' x 4.5"; 4.3 m x 11.2 cm) which ran from each end of the spacecraft to the center ring covering the length of three bays. Intercostals were T-shaped aluminum beams which were the vertical members on each side of all experiment bays between adjacent rows of longerons, and were ~39" x 4.5" (~99.1 x 11.2 cm) in size. A thick, continuous aluminum center ring was located between Bays C and D to provide LDEF with sufficient rigidity; it was on this ring that trunnion pins C03, C06, and C09 were attached to the spacecraft. The center of each end of the spacecraft (M&D SIG Bays G25 and H25) was occupied by an aluminum plate which had been riveted into position.

The M&D SIG A-Team surveyed the LDEF structural frame after all experiment trays, with the exception of the two grapple trays (C01 and C10), and thermal panels had been removed. All areas of the frame were surveyed, including the interior portions, which had not been covered during flight by either the experiment-tray flanges, experiment-tray clamps, thermal panels, or reflectors. The total surface area of the space-exposed frame amounted to ~24 m^2, and is a potentially valuable source of meteoroid and debris information.

During the M&D SIG survey a total of 5604 impact features were identified on all LDEF frame members; of these, 446 were ≥0.5 mm in diameter, or were considered to be of sufficient interest to warrant their photodocumentation. Three of these features were located on interior portions of the spacecraft and, in all cases, a plausible path could be found for the projectile to have passed, unscathed, to the area where it ultimately impacted.

Of the 5604 impact features, 4876 were located on the peripheral longerons and intercostals (Bays A01 through F12; 2240 on longerons and 2636 on intercostals), 649 were located on the space-end structural components (including H25), and 79 were located on the Earth-end structural components (including G25). Four thousand four hundred and eighty of the features which were counted on the peripheral frame members were <0.5 mm in diameter (14 of which were photodocumented), 337 were between 0.5 mm and 1.0 mm in diameter (including one ~0.5 mm in diameter feature which was on the interior portion of the D02 intercostal, but could not be photodocumented, and one which appeared to result from a multi-cratering event), 46 were between 1.0 mm and 1.5 mm in diameter, seven were between 1.5 mm and 2.0 mm in diameter (including one ~1.8 mm in diameter which was on the interior portion of the A10 longeron, but could not be photodocumented), and six were >2.0 mm (including one ~3.0 mm in diameter which was on the interior portion of the D09 longeron). Thirteen of these features were not craters, but were ejecta spray patterns which were associated with impacts into adjacent experiment-tray flanges or clamps. On the space-end, 613 features were <0.5 mm in diameter and were not photodocumented, 31 were between 0.5 mm and 1.0 mm in diameter, two were between 1.0 mm and 1.5 mm in diameter, two were between 1.5 mm and 2.0 mm in diameter, and one was >2.0 mm in diameter. Seventy eight of the 79 features on the Earth-end were <0.5 mm in diameter (four of which were photodocumented in one image), and one feature was ~0.7 mm in diameter.

FEATURE SUMMARY FOR INTERCOSTALS

	ROWS												
	1	2	3	4	5	6	7	8	9	10	11	12	Total
Bay A F02													
<0.5 mm	6	5	8	2	7	16	20	21	23	40	11	14	173
>0.5 mm	1	0	0	0	1	0	1	6	1	3	3	1	17
Total	7	5	8	2	8	16	21	27	24	43	14	15	190
Bay B F02													
<0.5 mm	14	3	5	7	16	20	30	40	43	38	28	37	281
>0.5 mm	0	0	0	0	1	1	2	0	0	4	2	1	11
Total	14	3	5	7	17	21	32	40	43	42	30	38	292
Bay C F02													
<0.5 mm	5	6	7	7	7	30	35	46	53	38	41	23	298
>0.5 mm	0	1	2	0	1	3	1	1	5	4	2	2	22
Total	5	7	9	7	8	33	36	47	58	42	43	25	320
Bay D F02													
<0.5 mm	24	17	11	16	25	62	91	223	164	78	145	74	930
>0.5 mm	2	1	0	3	4	4	7	21	12	18	12	6	90
Total	26	18	11	19	29	66	98	244	176	96	157	80	1020
Bay E F02													
<0.5 mm	5	3	9	7	7	27	24	32	60	44	16	17	251
>0.5 mm	1	0	0	0	0	1	0	1	5	7	2	1	18
Total	6	3	9	7	7	28	24	33	65	51	18	18	269
Bay F F02													
<0.5 mm	6	3	2	9	18	35	39	39	101	25	33	15	325
>0.5 mm	0	0	1	0	1	1	2	4	2	3	3	0	17
Total	6	3	3	9	19	36	41	43	103	28	36	15	342
Bay F F03													
<0.5 mm	5	5	3	4	13	26	17	33	7	46	21	7	187
>0.5 mm	2	2	0	0	0	1	2	5	0	3	0	1	16
Total	7	7	3	4	13	27	19	38	7	49	21	8	203
TOTALS													
<0.5 mm	65	42	45	52	93	216	256	434	451	309	295	187	2445
>0.5 mm	6	4	3	3	8	11	15	38	25	42	24	12	191
Total	71	46	48	55	10	227	271	472	476	351	319	199	2636

FEATURE SUMMARY FOR LONGERONS

INTER-ROW POSITIONS

	1	2	3	4	5	6	7	8	9	10	11	12	Total
Bay A F01													
<0.5 mm	8	3	3	12	12	28	49	84	60	50	24	22	355
>0.5 mm	1	0	1	0	0	1	7	7	9	9	4	3	42
Total	9	3	4	12	12	29	56	91	69	659	28	25	397
Bay B F01													
<0.5 mm	4	2	3	8	12	42	53	62	44	50	11	19	310
>0.5 mm	1	0	0	0	2	3	7	4	7	8	1	0	33
Total	5	2	3	8	14	45	60	66	51	58	12	19	343
Bay C F01													
<0.5 mm	6	5	4	6	6	32	54	79	64	41	31	9	337
>0.5 mm	1	1	0	1	0	1	6	7	10	5	3	1	36
Total	7	6	4	7	6	33	60	86	74	46	34	10	373
Bay D F01													
<0.5 mm	5	6	4	5	11	42	43	68	49	25	23	11	292
>0.5 mm	0	0	0	0	0	4	5	7	6	8	1	7	38
Total	5	6	4	5	11	46	48	75	55	33	24	18	330
Bay E F01													
<0.5 mm	6	2	7	5	19	25	30	71	101	50	33	19	368
>0.5 mm	1	0	0	0	0	1	1	4	6	3	2	5	23
Total	7	2	7	5	19	26	31	75	107	53	35	24	391
Bay F F01													
<0.5 mm	5	3	4	4	18	35	43	70	86	46	35	24	373
>0.5 mm	3	0	0	0	3	1	3	3	6	6	6	2	33
Total	8	3	4	4	21	36	46	73	92	52	41	26	406
TOTALS													
<0.5 mm	34	21	25	40	78	204	272	434	404	262	157	104	2035
>0.5 mm	7	1	1	1	5	11	29	32	44	39	17	18	205
Total	41	22	26	41	83	215	301	466	448	301	174	122	2240

FEATURE SUMMARY FOR EARTH- (G) AND SPACE-END (H)

	Total
Bay G	
<0.5 mm	78
>0.5 mm	1
Total	79
Bay H	
<0.5 mm	613
>0.5 mm	36
Total	649

The largest impact features found on the LDEF frame were (1) an ~3.3 mm diameter feature on the E11 intercostal, (2) an ~3.0 mm diameter feature on the inside of intercostal D09, (3) an ~2.1 mm diameter feature on the space-end, and (4) an ~0.7 mm diameter feature on the Earth-end. Many interesting ejecta spray patterns were encountered during the course of this survey, and since many of these features were present on frame members which could not be removed from the spacecraft, tape lifts were performed on many of these ejecta deposits in an attempt to recover impactor residue. The resulting tape-lifts samples are archived at the Johnson Space Center (JSC).

Due to the interesting nature and distribution of several features identified on the LDEF frame, the M&D SIG A-Team requested various intercostals from the LDEF Project Office. The LDEF Project Office ultimately provided nine intercostals to the M&D SIG which presently has these frame members archived at the JSC.

M&D SIG INSPECTION

DOCUMENTATION:

Examination and photodocumentation of the LDEF frame was conducted on a row-by-row basis, with the intercostal from a particular row being documented at the same time as the longeron from the preceding row. The survey was accomplished during marathon evening sessions from April 2 through April 10, 1990, utilizing M&D SIG Systems #2 and #3. Coordinates for photodocumented features were measured with a metric tape measure from the corner formed by the intersection of the longeron and intercostal associated with a particular bay, the same corner which was located directly behind the experiment-tray flanges were the (0,0) reference point was defined for the various experiment trays (see Section 2.C.6.a). Because the frame survey was conducted on the opposite side of the spacecraft from the Ground Operations deintegration platform, the intersection of the longeron and intercostal which defined the (0,0) reference point appeared in the upper right-hand portion of the bay when viewed from the flat-bed trailer. As a result, positive X-values were measured to the left, and positive Y-values down from the (0,0) reference point. The survey is organized below according to (1) LDEF rows (1 to 12), on which the intercostals lie, (2) inter-row areas, where the longerons belong (with the longeron lying between rows 1 and 2 being designated "1-2"), and (3) spacecraft ends (Earth- and space-facing), including the center-end plates G25 and H25, respectively.

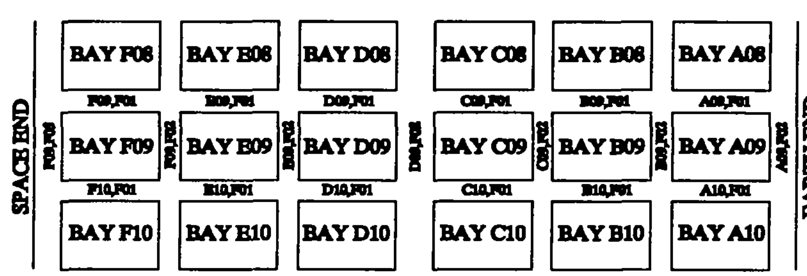

Figure LF-1. Illustration of the scheme adopted by the M&D SIG for identifying the Longeron and Intercostal frame components.

Each Bay possessed two intercostals, one being towards the Earth-end of LDEF, the second being towards the space-end. Since all but the end bays (Bays A and F) shared intercostals, the M&D SIG derived a scheme by which each intercostal was assigned to a particular bay location and given an M&D SIG "Component Number" to designate its location on the spacecraft. Each intercostal was assigned to the bay to its immediate left, when viewing the spacecraft with the Earth-end to the right and the space-end to the left, and given Component Number F02. The odd intercostal, which was located on the space-end of Bay F of each row, was considered a second intercostal for Bay F and assigned Component Number F03 (Figure LF-1). The center-ring frame member was treated as though it was an intercostal of Bay D. The extra width of the Center-ring frame member verses that of ordinary intercostals (~35.5 cm verses ~11.2 cm) explains the systematically higher number of features associated with this frame component. Longerons were always assigned Component Number F01, and were assigned to the bays for which they were the bottom member (as viewed from the Ground Operations deintegration platform).

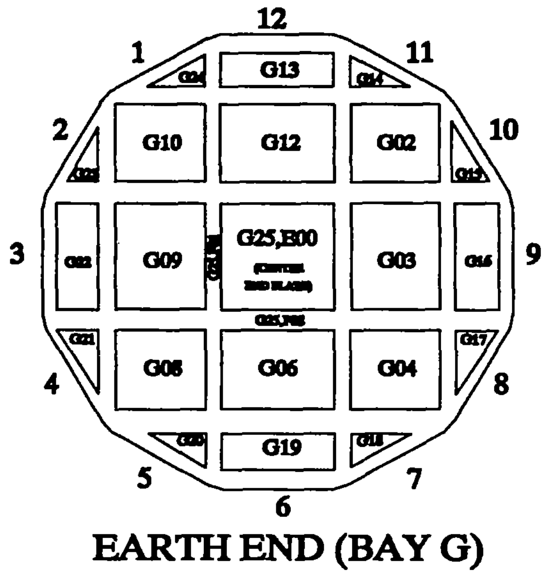

Figure LF-2. Diagram showing the names of only those Earth-facing frame members on which features were identified.

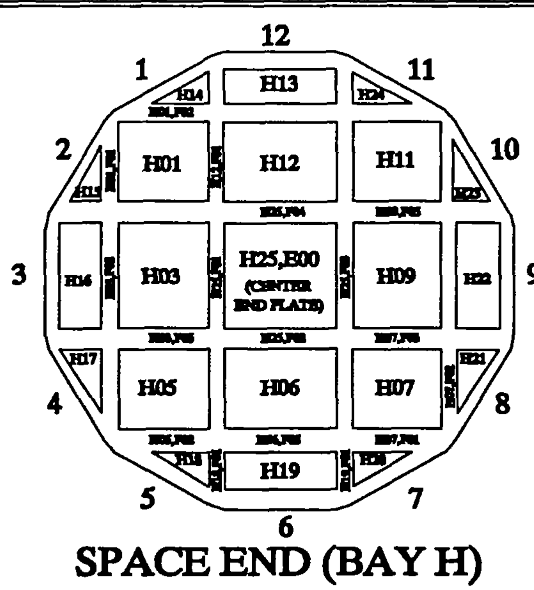

Figure LF-3. Diagram showing the names of only those space-facing frame members on which features were identified.

For the LDEF Earth- and space-facing ends, nomenclature of the longerons and intercostals is more complex, and Figures LF-2 and LF-3 should be consulted. Also surveyed were the center-end plates (G25 and H25) which served as attachment points between the spacecraft and the LDEF Assembly and Transportation System. These center-end plates were not removable, but were surveyed along with the rest of the frame members. Note that no features were located or documented on the Earth-end center plate (Bay G25, Component Number E00).

Impact Features Imaged on Exposed Frame Surfaces

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
Longeron Between Rows 12 and 1							
LF010001.A01	RF010001.A01	915	-50		0.7	Al	
LF010001.B01	RF010001.B01	504	-54		0.6	Al	
LF010001.C01	RF010001.C01	388	-45		0.6	Al	
LF010001.E01	RF010001.E01	-18	-40		0.7	Al	
LF010001.F01	RF010001.F01	-44	-27		0.7	Al	
AF010001.F01	BF010001.F01	-44	-27		0.7	Al	
LF010002.F01	RF010002.F01	1298	-65		0.9	Al	*1,l*
LF010003.F01	RF010003.F01	1418	-31		0.8	Al	
Row 1 Intercostals							
LF020001.A01	RF020001.A01	-15	965		0.7	Al	
LF020001.D01	RF020001.D01	-6	28		0.8	Al	
LF020002.D01	RF020002.D01	-56	417		0.7	Al	
LF020001.E01	RF020001.E01	-51	978		0.6	Al	
LF030001.F01	RF030001.F01	1350	580		1.4	Al	
LF030002.F01	RF030002.F01	1360	860		0.9	Al	
Longeron Between Rows 1 and 2							
LF010001.C02	RF010001.C02	540	-60		0.3 x 0.5	Al	
LF010002.C02	RF010002.C02	1105	-63		0.8	Al	
Row 2 Intercostals							
LF020001.C02	RF020001.C02	-39	800		0.6	Al	
LF030001.F02	RF030001.F02	1335	365		0.7	Al	
AF030001.F02	BF030001.F02	1335	365		0.7	Al	
LF030002.F02	RF030002.F02	1310	777		0.6	Al	
Longeron Between Rows 2 and 3							
LF010001.A03	RF010001.A03	307	-70		0.7	Al	
Row 3 Intercostals							
LF020001.C03	RF020001.C03	-62	353		0.5	Al	
LF020002.C03	RF020002.C03	-33	662		0.8	Al	
LF020001.F03	RF020001.F03	-37	115		0.6	Al	
Longeron Between Rows 3 and 4							
LF010001.C04	RF010001.C04	368	-63		0.6	Al	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
Row 4 Intercostals							
LF020001.D04	RF020001.D04	-140	20		1.2	Al	
LF020002.D04	RF020002.D04	-283	145		1.2	Al	
LF020003.D04	RF020003.D04	-95	905		1.5	Al	
Longeron Between Rows 4 and 5							
LF010001.B05	RF010001.B05	198	-80		1.1	Al	
LF010002.B05	RF010002.B05	130	-62		0.8	Al	
LF010001.D05	RF010001.D05	1080	-82		0.4	Al	
LF010001.F05	RF010001.F05	248	-55		0.6	Al	
LF010002.F05	RF010002.F05	736	-46		0.5	Al	
LF010003.F05	RF010003.F05	1341	-40		0.5	Al	
Row 5 Intercostals							
LF020001.A05	RF020001.A05	-43	363		0.7	Al	
LF020001.B05	RF020001.B05	-27	175		0.4 x 0.5	Al	
LF020002.B05	RF020002.B05	-3	985		0.6	Al	
LF020001.C05	RF020001.C05	-65	358		0.7	Al	
LF020001.D05	RF020001.D05	-233	169		0.5	Al	
LF020002.D05	RF020002.D05	-104	560		0.5	Al	
LF020003.D05	RF020003.D05	-252	585		0.5	Al	
LF020004.D05	RF020004.D05	-108	770		0.6	Al	
LF020005.D05	RF020005.D05	-290	750		0.5 x 0.7	Al	
LF020001.F05	RF020001.F05	-37	768		0.8	Al	
Longeron Between Rows 5 and 6							
LF010001.A06	RF010001.A06	225	-79		1.0	Al	
LF010001.B06	RF010001.B06	-97	-81		1.1	Al	
LF010002.B06	RF010002.B06	196	-68		0.7	Al	
LF010003.B06	RF010003.B06	1023	-82		1.0	Al	*d*
LF010001.C06	RF010001.C06	1110	-78		0.8	Al	
LF010001.D06	RF010001.D06	-90	-17		0.5	Al	
LF010002.D06	RF010002.D06	-263	-15		1.2	Al	
LF010003.D06	RF010003.D06	200	-52		0.7	Al	
LF010004.D06	RF010004.D06	340	-80		0.6	Al	
LF010001.E06	RF010001.E06	220	-80		0.7	Al	
LF010001.F06	RF010001.F06	740	-68		0.7	Al	
Row 6 Intercostals							
LF020001.A06	RF020001.A06	-74	768		0.4 x 0.7	Al	
AF020001.A06	BF020001.A06	-74	768		0.4 x 0.7	Al	
LF020001.B06	RF020001.B06	-67	689		0.5	Al	*j*
AF020001.B06	BF020001.B06	-67	689		0.5	Al	*j*
LF020001.C06	RF020001.C06	-74	148		0.7	Al	
LF020002.C06	RF020002.C06	-55	280		0.5	Al	
LF020003.C06	RF020003.C06	-64	882		0.5	Al	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LF020001.D06	RF020001.D06	-85	162		0.7	Al	
LF020002.D06	RF020002.D06	-146	265		1.0	Al	*d*
LF020003.D06	RF020003.D06	-45	960		1.0	Weld	
LF020004.D06	RF020004.D06	-155	725		0.7	Al	
LF020001.E06	RF020001.E06	-40	610		0.5	Al	
LF020001.F06	RF020001.F06	-85	135		0.5 x 0.6	Al	
LF030001.F06	RF030001.F06	1345	35		0.8	Al	

Longeron Between Rows 6 and 7

LF010001.A07	RF010001.A07	-76	-55		0.7	Al	
LF010002.A07	RF010002.A07	-16	-63		0.3 x 0.5	Al	*d*
LF010003.A07	RF010003.A07	428	-39		0.9	Al	
LF010004.A07	RF010004.A07	465	-79		0.5	Al	
LF010005.A07	RF010005.A07	730	-51		0.5	Al	
LF010006.A07	RF010006.A07	923	-64		0.5	Al	
LF010007.A07	RF010007.A07	1018	-80		0.6	Al	
LF010008.A07	RF010008.A07	1132	-42		0.8	Al	
LF010001.B07	RF010001.B07	180	-69		0.8	Al	
LF010002.B07	RF010002.B07	300	-35		0.9	Al	
LF010003.B07	RF010003.B07	430	-25			Al	*10,24*
LF010004.B07	RF010004.B07	446	-70		0.6	Al	
LF010005.B07	RF010005.B07	740	-54		0.5	Al	
LF010006.B07	RF010006.B07	895	-84		0.6	Al	
AF010006.B07	BF010006.B07	895	-84		0.6	Al	*28*
LF010007.B07	RF010007.B07	1215	-54		0.5	Al	
LF010001.C07	RF010001.C07	-73	-65		0.6	Al	
LF010002.C07	RF010002.C07	248	-31		0.7	Al	
LF010003.C07	RF010003.C07	678	-65		0.5	Al	
LF010004.C07	RF010004.C07	902	-31		0.5	Al	
LF010005.C07	RF010005.C07	914	-36		0.6	Al	
LF010006.C07	RF010006.C07	1137	-65		1.0	Al	
LF010001.D07	RF010001.D07	270	-58		0.6	Al	
LF010002.D07	RF010002.D07	785	-80		0.5	Al	
LF010003.D07	RF010003.D07	1090	-56		1.3	Al	
LF010004.D07	RF010004.D07	-70	-25		0.5	Al	
LF010005.D07	RF010005.D07	-90	-90		0.6	Al	
LF010001.E07	RF010001.E07	356	-65		0.5	Al	
LF010001.F07	RF010001.F07	285	-32		0.7	Al	
LF010002.F07	RF010002.F07	580	-78		1.3	Al	
LF010003.F07	RF010003.F07	900	-58		0.7	Al	

Row 7 Intercostals

LF020001.A07	RF020001.A07	-30	160		0.7	Al	
LF020001.B07	RF020001.B07	-79	755		0.6	Al	
LF020002.B07	RF020002.B07	-39	158		0.6	Al	
LF020003.B07	RF020003.B07	-36	220		0.5 x 0.7	Al	
LF020001.C07	RF020001.C07	-81	780		0.5	Al	
AF020001.C07	BF020001.C07	-81	780		0.5	Al	
LF020001.D07	RF020001.D07	-100	100		0.5	Al	*11*
LF020002.D07	RF020002.D07	-220	212		0.5	Al	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LF020003.D07	RF020003.D07	-277	404		0.6	Al	
LF020004.D07	RF020004.D07	-215	432		0.9	Al	
LF020005.D07	RF020005.D07	-213	625		0.5	Al	
LF020006.D07	RF020006.D07	-94	685		1.5	Al	
LF020007.D07	RF020007.D07	-30	830		0.5	Al	
LF020008.D07	RF020008.D07	-40	925		2.5 x 2.8	Weld	
LF020001.E07	RF020001.E07	-65	50		0.4 x 0.5	Al	
LF020001.F07	RF020001.F07	-78	18		0.7	Al	
LF020002.F07	RF020002.F07	-85	900			Al	*10*
LF030001.F07	RF030001.F07	1340	510		1.3	Al	
LF030002.F07	RF030002.F07	1315	395			Al	*10*

Longeron Between Rows 7 and 8

LF010001.A08	RF010001.A08	455	-63		1.0	Al	
LF010002.A08	RF010002.A08	468	-21		0.8	Al	*d*
LF010003.A08	RF010003.A08	531	-42		0.5	Al	
LF010004.A08	RF010004.A08	570	-42		0.8	Al	
LF010005.A08	RF010005.A08	755	-55		0.8	Al	
LF010006.A08	RF010006.A08	890	-48		0.5	Al	
LF010007.A08	RF010007.A08	891	-51		0.6	Al	
LF010001.B08	RF010001.B08	-78	-33		0.9	Al	
LF010002.B08	RF010002.B08	265	-88		0.8	Al	
LF010003.B08	RF010003.B08	485	-73		0.6	Al	
LF010004.B08	RF010004.B08	768	-54		0.6	Al	
LF010001.C08	RF010001.C08	-28	-40		0.8	Al	
LF010002.C08	RF010002.C08	37	-59		0.5	Al	
LF010003.C08	RF010003.C08	144	-48		0.6	Al	
LF010004.C08	RF010004.C08	288	-45		0.6	Al	
LF010005.C08	RF010005.C08	985	-48		0.5	Al	
LF010006.C08	RF010006.C08	1078	-30		0.9	Al	
LF010007.C08	RF010007.C08	1095	-82		0.7	Al	
LF010001.D08	RF010001.D08	-203	-40		0.5	Al	
AF010001.D08	BF010001.D08	-203	-40		0.5	Al	
LF010002.D08	RF010002.D08	185	-70		0.8	Al	
LF010003.D08	RF010003.D08	355	-57		1.3	Al	
LF010004.D08	RF010004.D08	820	-33		0.5	Al	
LF010005.D08	RF010005.D08	910	-56		0.5	Al	
LF010006.D08	RF010006.D08	927	-65		0.9	Al	
LF010007.D08	RF010007.D08	1020	-40		0.7	Al	
LF010001.E08	RF010001.E08	130	-27		0.5	Al	*d*
LF010002.E08	RF010002.E08	150	-72		0.9	Al	
LF010003.E08	RF010003.E08	435	-55		0.6	Al	
AF010003.E08	BF010003.E08	435	-55		0.6	Al	
LF010004.E08	RF010004.E08	502	-67		1.0	Al	*d*
LF010005.E08	RF010005.E08	745	-27		0.5	Al	*d*
LF010001.F08	RF010001.F08	440	-63		0.6	Al	
LF010002.F08	RF010002.F08	889	-60		0.7	Al	
LF010003.F08	RF010003.F08	1314	-68		0.9	Al	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
Row 8 Intercostals							
LF020001.A08	RF020001.A08	-32	206		0.9 x 1.0	Al	*2*
LF020002.A08	RF020002.A08	-47	615		1.1	Al	
LF020003.A08	RF020003.A08	-45	737		0.5	Al	
LF020004.A08	RF020004.A08	-49	840		1.2	Al	
LF020005.A08	RF020005.A08	-63	885		0.9	Al	
LF020006.A08	RF020006.A08	-72	186		0.5	Al	
LF020001.C08	RF020001.C08	-68	407		0.5	Al	
LF020001.D08	RF020001.D08	-315	270		0.5	Al	
LF020002.D08	RF020002.D08	-215	417		0.6	Al	
LF020003.D08	RF020003.D08	-83	81		0.6	Al	
LF020004.D08	RF020004.D08	-234	92		0.4 x 0.7	Al	*d*
LF020005.D08	RF020005.D08	-220	158		0.5	Al	
LF020006.D08	RF020006.D08	-258	158		0.5	Al	
LF020007.D08	RF020007.D08	-52	145		0.5	Al	
LF020008.D08	RF020008.D08	-193	220		1.1 x 1.4	Al	*d*
LF020009.D08	RF020009.D08	-102	270		1.1	Al	
LF020010.D08	RF020010.D08	-227	270		0.5	Al	
LF020011.D08	RF020011.D08	-234	265		0.5	Al	
LF020012.D08	RF020012.D08	-285	278		1.3	Al	
LF020013.D08	RF020013.D08	-185	340		0.8	Al	
LF020014.D08	RF020014.D08	-190	350		0.6	Al	
LF020015.D08	RF020015.D08	-117	660		0.6	Al	*3*
LF020016.D08	RF020016.D08	-120	595		0.6	Al	*26*
LF020017.D08	RF020017.D08	-194	779		0.8	Al	
LF020018.D08	RF020018.D08	-235	772		0.7	Al	
LF020019.D08	RF020019.D08	-254	878		0.5	Al	
LF020020.D08	RF020020.D08	-45	845		2.6	Weld	
LF020021.D08	RF020021.D08	-275	563		0.8	Al	
AF020021.D08	BF020021.D08	-275	563		0.8	Al	
LF020022.D08	RF020022.D08	-180	457		1.0	Al	
LF020001.E08	RF020001.E08	-27	183		0.4	Al	*d*
LF020002.E08	RF020002.E08	-76	715		0.6	Al	
LF020001.F08	RF020001.F08	-55	130		1.2	Al	
LF020002.F08	RF020002.F08	-77	580		0.5	Al	
LF020003.F08	RF020003.F08	-55	740		0.8	Al	
LF020004.F08	RF020004.F08	-58	785		0.7	Al	
LF030001.F08	RF030001.F08	1328	20		0.5	Al	
LF030002.F08	RF030002.F08	1355	740		0.5	Al	
LF030003.F08	RF030003.F08	1333	677		0.6	Al	
LF030004.F08	RF030004.F08	1353	910		0.7	Al	
LF030005.F08	RF030005.F08	1319	921		0.5	Al	*d*
Longeron Between Rows 8 and 9							
LF010001.A09	RF010001.A09	-155	-50		1.1	Al	*22*
LF010002.A09	RF010002.A09	-155	-50		1.1	Al	*22*
LF010003.A09	RF010003.A09	-101	-2		1.1	Al	
LF010004.A09	RF010004.A09	130	-56		0.5	Al	
LF010005.A09	RF010005.A09	145	-75		0.5	Al	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LF010006.A09	RF010006.A09	424	-44		0.6	Al	
LF010007.A09	RF010007.A09	710	-63			Al	*1,10,d*
LF010008.A09	RF010008.A09	805	-62		0.5	Al	
LF010009.A09	RF010009.A09	923	-51		1.0	Al	
LF010010.A09	RF010010.A09	1124	-52		0.6	Al	
LF010001.B09	RF010001.B09	-107	100		0.5	Al	
LF010002.B09	RF010002.B09	-91	-58		0.5	Al	
LF010003.B09	RF010003.B09	-78	-40		0.5	Al	
LF010004.B09	RF010004.B09	-20	-68		0.5	Al	
LF010005.B09	RF010005.B09	326	-31		0.5	Al	
LF010006.B09	RF010006.B09	342	-66		0.7	Al	
LF010007.B09	RF010007.B09	512	-80		1.0	Al	
LF010001.C09	RF010001.C09	-87	-40		0.6	Al	
LF010002.C09	RF010002.C09	-94	-80		0.6	Al	
LF010003.C09	RF010003.C09	-40	-85		1.3	Al	
LF010004.C09	RF010004.C09	240	-42		0.7	Al	
LF010005.C09	RF010005.C09	275	-74		0.9	Al	
LF010006.C09	RF010006.C09	285	-66		0.9	Al	
LF010007.C09	RF010007.C09	468	-51		0.6	Al	
LF010008.C09	RF010008.C09	737	-69		0.5	Al	
LF010009.C09	RF010009.C09	995	-33		0.9	Al	
LF010010.C09	RF010010.C09	1175	-43		0.7	Al	
LF010001.D09	RF010001.D09	-175	-75		0.6	Al	*35*
LF010002.D09	RF010002.D09	435	-40		0.5	Al	
LF010003.D09	RF010003.D09	515	-75		0.7	Al	
LF010004.D09	RF010004.D09	760	-70		0.7	Al	
LF010005.D09	RF010005.D09	1160	-45		0.7	Al	
LF010006.D09	RF010006.D09	1285	-55	150	3.0	Al	*12*
LF010001.E09	RF010001.E09	-60	-55		0.6	Al	
LF010002.E09	RF010002.E09	270	-30		0.6	Al	
LF010003.E09	RF010003.E09	395	-48		0.5	Al	
LF010004.E09	RF010004.E09	414	-80		0.5	Al	
LF010005.E09	RF010005.E09	463	-35		0.5	Al	*36*
LF010006.E09	RF010006.E09	1081	-58		0.7	Al	
LF010001.F09	RF010001.F09	230	-38		0.5	Al	
LF010002.F09	RF010002.F09	280	-62		0.5	Al	
LF010003.F09	RF010003.F09	390	-27		0.6	Al	
LF010004.F09	RF010004.F09	794	-52		1.2	Al	
LF010005.F09	RF010005.F09	842	-65		0.6	Al	
LF010006.F09	RF010006.F09	1325	-63		0.5	Al	

Row 9 Intercostals

LF020001.A09	RF020001.A09	-51	772		1.5	Al	
LF020001.C09	RF020001.C09	-80	286		0.7	Al	
LF020002.C09	RF020002.C09	-29	268		0.8	Al	
LF020003.C09	RF020003.C09	-84	136		0.6	Al	
LF020004.C09	RF020004.C09	-86	98		0.6	Al	
LF020005.C09	RF020005.C09	-50	470		0.7	Al	
LF020001.D09	RF020001.D09	-159	987		1.0	Al	
LF020002.D09	RF020002.D09	-165	950		0.5	Al	
LF020003.D09	RF020003.D09	-263	910		0.5	Al	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LF020004.D09	RF020004.D09	-251	860		0.7	Al	
LF020005.D09	RF020005.D09	-146	833		0.5	Al	
LF020006.D09	RF020006.D09	-62	780		1.0	Al	
LF020007.D09	RF020007.D09	-160	745		1.2	Al	*23*
LF020008.D09	RF020008.D09	-115	530		0.6	Al	
LF020009.D09	RF020009.D09	-115	580		0.5	Al	
LF020010.D09	RF020010.D09	-220	540		0.7	Al	
LF020011.D09	RF020011.D09	-271	560		0.8	Al	
LF020012.D09	RF020012.D09	-130	460		0.6	Al	
LF020001.E09	RF020001.E09	-45	65		0.6	Al	
LF020002.E09	RF020002.E09	-40	190		0.6	Al	
LF020003.E09	RF020003.E09	-60	445		0.6	Al	
LF020004.E09	RF020004.E09	-68	590		1.4	Al	
LF020005.E09	RF020005.E09	-30	710		0.7	Al	
LF020001.F09	RF020001.F09	-50	65		1.2	Al	
LF020002.F09	RF020002.F09	-85	820		0.7	Al	
Longeron Between Rows 9 and 10							
LF010001.A10	RF010001.A10	302	-26		0.6	Al	
LF010002.A10	RF010002.A10	460	-29		0.7	Al	
AF010002.A10	BF010002.A10	460	-29		0.7	Al	
LF010003.A10	RF010003.A10	522	-46		1.4	Al	
AF010003.A10	BF010003.A10	522	-46		1.4	Al	
CF010003.A10	DF010003.A10	522	-46		1.4	Al	
LF010004.A10	RF010004.A10	1012	-30		0.5	Al	
AF010004.A10	BF010004.A10	1012	-30		0.5	Al	
CF010004.A10	DF010004.A10	1012	-30		0.5	Al	
LF010005.A10	RF010005.A10	1013	-71		0.7	Al	
LF010006.A10	RF010006.A10	1055	-81		0.8	Al	
LF010007.A10	RF010007.A10	1106	-36		0.6	Al	
LF010008.A10	RF010008.A10	1112	-58		0.6	Al	
LF010001.B10	RF010001.B10	-21	-81		0.5	Al	
LF010002.B10	RF010002.B10	150	-55		0.9	Al	
LF010003.B10	RF010003.B10	313	-46		0.5	Al	
LF010004.B10	RF010004.B10	390	-70		0.5	Al	
LF010005.B10	RF010005.B10	430	-58		0.6	Al	
LF010006.B10	RF010006.B10	550	-45		0.5	Al	
LF010007.B10	RF010007.B10	722	-51		0.7	Al	
LF010008.B10	RF010008.B10	1021	-29		1.1	Al	
LF010001.C10	RF010001.C10	-72	-88		0.7 x 2.3	Al	*d*
LF010002.C10	RF010002.C10	455	-35		0.5	Al	
LF010003.C10	RF010003.C10	565	-90			Al	*4,10,20,d*
LF010004.C10	RF010004.C10	1010	-65		0.5	Al	
LF010005.C10	RF010005.C10	1134	-72		1.5	Al	
LF010001.D10	RF010001.D10	-315	-75		0.8	Al	
LF010002.D10	RF010002.D10	-191	-20		0.6	Al	
LF010003.D10	RF010003.D10	-85	-50		0.6	Al	
LF010004.D10	RF010004.D10	150	-50		0.7	Al	
LF010005.D10	RF010005.D10	151	-72		1.0	Al	
LF010006.D10	RF010006.D10	333	-58		0.6	Al	*6*
LF010007.D10	RF010007.D10	490	-35		0.5	Al	*7*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LF010008.D10	RF010008.D10	1110	-72		1.0	Al	*8*
LF010001.E10	RF010001.E10	155	-52		0.5	Al	
LF010002.E10	RF010002.E10	760	-40		0.7	Al	*34*
LF010003.E10	RF010003.E10	1000	-72		1.6	Al	
LF010001.F10	RF010001.F10	515	-48		0.6	Al	*33*
LF010002.F10	RF010002.F10	555	-46		0.6	Al	*32*
LF010003.F10	RF010003.F10	570	-84			Al	*4*
LF010004.F10	RF010004.F10	855	-32		0.5	Al	
LF010005.F10	RF010005.F10	1084	-33		0.5	Al	
LF010006.F10	RF010006.F10	1457	-74		0.6	Al	*9*

Row 10 Intercostals

LF020001.A10	RF020001.A10	-63	594		0.6	Al	
LF020002.A10	RF020002.A10	-44	665		0.6	Al	
LF020003.A10	RF020003.A10	-44	255		0.6	Al	
AF020003.A10	BF020003.A10	-44	255		0.6	Al	
LF020001.B10	RF020001.B10	-65	130		0.6	Al	
LF020002.B10	RF020002.B10	-63	480		0.8	Al	
LF020003.B10	RF020003.B10	-74	778		0.5	Al	
LF020004.B10	RF020004.B10	-64	836		1.7	Al	
LF020001.C10	RF020001.C10	-40	58		0.6	Al	
LF020002.C10	RF020002.C10	-57	98		0.6	Al	
LF020003.C10	RF020003.C10	-74	195		1.1	Al	
LF020004.C10	RF020004.C10	-60	340		0.5	Al	
LF020001.D10	RF020001.D10	-160	30		0.7	Al	
LF020002.D10	RF020002.D10	-155	70		0.7	Al	
LF020003.D10	RF020003.D10	-30	85		0.5	Al	
LF020004.D10	RF020004.D10	-172	304		0.9	Al	
LF020005.D10	RF020005.D10	-293	390		0.7	Al	
LF020006.D10	RF020006.D10	-164	546		0.5	Al	
LF020007.D10	RF020007.D10	-69	572		0.6	Al	
LF020008.D10	RF020008.D10	-300	580		1.0	Al	
LF020009.D10	RF020009.D10	-122	600		0.6	Al	
LF020010.D10	RF020010.D10	-292	973		0.6	Al	
LF020011.D10	RF020011.D10	-63	890		1.0	Al	
LF020012.D10	RF020012.D10	-240	862		0.9	Al	
LF020013.D10	RF020013.D10	-205	825		0.6	Al	
LF020014.D10	RF020014.D10	-100	780		0.8	Al	
LF020015.D10	RF020015.D10	-268	783		0.6	Al	
LF020016.D10	RF020016.D10	-287	720		1.2	Al	
LF020017.D10	RF020017.D10	-145	699		0.5	Al	
LF020018.D10	RF020018.D10	-305	675		0.5 x 0.8	Al	*21*
LF020001.E10	RF020001.E10	-70	275		0.8	Al	
LF020002.E10	RF020002.E10	-88	310			Al	*10*
LF020003.E10	RF020003.E10	-33	603		0.6	Al	
LF020004.E10	RF020004.E10	-53	645		0.6	Al	
LF020005.E10	RF020005.E10	-61	855		0.6	Al	
LF020006.E10	RF020006.E10	-15	970		0.6	Al	
LF020007.E10	RF020007.E10	-59	965		1.2	Al	
LF020001.F10	RF020001.F10	-45	880		0.5	Al	
LF020002.F10	RF020002.F10	-75	878		0.6	Al	

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LF020003.F10	RF020003.F10	-75	840		0.6	Al	
LF030001.F10	RF030001.F10	1355	145		0.7	Al	
LF030002.F10	RF030002.F10	1345	300		0.6	Al	
LF030003.F10	RF030003.F10	1333	785		0.5	Al	

Longeron Between Rows 10 and 11

LF010001.A11	RF010001.A11	-69	-28		0.9	Al	
LF010002.A11	RF010002.A11	694	-59		0.6	Al	
LF010003.A11	RF010003.A11	713	-86		1.0	Al	*18*
AF010003.A11	BF010003.A11	713	-86		1.0	Al	*18*
LF010004.A11	RF010004.A11	748	-44		0.5	Al	
LF010001.B11	RF010001.B11	167	-37		0.5	Al	
LF010001.C11	RF010001.C11	-45	-43		0.5	Al	
LF010002.C11	RF010002.C11	315	-41		0.7	Al	
LF010003.C11	RF010003.C11	681	-62		0.6	Al	*19,d*
LF010001.D11	RF010001.D11	-9	-110		0.8	Al	*31*
LF010001.E11	RF010001.E11	753	-32		0.7	Al	
LF010003.E11	RF010003.E11	1114	-80		0.8	Al	
LF010001.F11	RF010001.F11	132	-45		1.2	Al	
LF010002.F11	RF010002.F11	292	-85		0.5	Al	
LF010003.F11	RF010003.F11	455	-65		0.5	Al	
LF010004.F11	RF010004.F11	785	-65		0.7	Al	
LF010005.F11	RF010005.F11	1204	-57		0.7	Al	
LF010006.F11	RF010006.F11	1409	-75		0.5	Al	

Row 11 Intercostals

LF020001.A11	RF020001.A11	-31	870		1.2	Al	
LF020002.A11	RF020002.A11	-67	174			Al	*10*
LF020003.A11	RF020003.A11	-64	188		0.9	Al	
LF020001.B11	RF020001.B11	-55	417		0.7	Al	
LF020002.B11	RF020002.B11	-45	855		1.6	Al	*d*
LF020001.C11	RF020001.C11	-30	242		1.2	Al	
LF020002.C11	RF020002.C11	-43	865		0.9	Al	
LF020001.D11	RF020001.D11	216	300		1.2	Al	
LF020002.D11	RF020002.D11	210	297		1.6	Al	
LF020003.D11	RF020003.D11	-158	400		0.5	Al	
LF020004.D11	RF020004.D11	-181	500		0.7	Al	
LF020005.D11	RF020005.D11	-265	510		1.0	Al	
LF020006.D11	RF020006.D11	-201	690		0.5	Al	
LF020007.D11	RF020007.D11	-91	705		0.5	Al	
LF020008.D11	RF020008.D11	-65	730		0.5	Al	
LF020009.D11	RF020009.D11	-141	723		3.0	Al	
LF020010.D11	RF020010.D11	-140	780		0.8	Al	
LF020011.D11	RF020011.D11	-220	980		0.6	Al	
LF020012.D11	RF020012.D11	-340	985		0.7	Al	
LF020001.E11	RF020001.E11	-54	920		0.7	Al	
LF020002.E11	RF020002.E11	-76	935		3.3	Al	
LF020001.F11	RF020001.F11	-68	560		0.7	Al	
AF020001.F11	BF020001.F11	-68	560		0.7	Al	
LF020002.F11	RF020002.F11	-48	675		0.7	Al	*27*

IMAGE FILE NAMES LEFT	RIGHT	COORDINATES (mm) X	Y	Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LF020003.F11	RF020003.F11	-62	565		0.6	Al	*29*

Longeron Between Rows 11 and 12

LF010001.A12	RF010001.A12	-157	-63		0.7	Al	
AF010001.A12	BF010001.A12	-157	-63		0.7	Al	
LF010002.A12	RF010002.A12	865	-83			Al	*10*
LF010003.A12	RF010003.A12	960	-89		0.7	Al	*4,d*
AF010003.A12	BF010003.A12	960	-89		0.7	Al	*4,d*
CF010003.A12	DF010003.A12	960	-89		0.7	Al	*4,d*
EF010003.A12	FF010003.A12	960	-89		0.7	Al	*4,d*
GF010003.A12	HF010003.A12	960	-89		0.7	Al	*4,d*
LF010001.C12	RF010001.C12	812	-33		0.7 x 0.8	Al	
LF010001.D12	RF010001.D12	-20	-93		0.5	Al	
LF010002.D12	RF010002.D12	-30	-95		0.6	Al	
AF010002.D12	BF010002.D12	-30	-95		0.6	Al	
LF010003.D12	RF010003.D12	205	-78		0.8	Al	
LF010004.D12	RF010004.D12	470	-80		0.6	Al	*30*
LF010005.D12	RF010005.D12	515	-55		0.5	Al	
LF010006.D12	RF010006.D12	545	-35		1.0	Al	
LF010007.D12	RF010007.D12	990	-68		0.5	Al	
LF010001.E12	RF010001.E12	-108	-50		0.5	Al	
LF010002.E12	RF010002.E12	108	-85			Al	*4,e*
LF010003.E12	RF010003.E12	350	-50		0.5	Al	
LF010004.E12	RF010004.E12	475	-32		1.0	Al	
AF010004.E12	BF010004.E12	475	-32		1.0	Al	*5*
LF010005.E12	RF010005.E12	550	-60		0.5	Al	
LF010001.F12	RF010001.F12	460	-40		2.5	Al	
LF010002.F12	RF010002.F12	857	-30		0.5 x 0.9	Al	

Row 12 Intercostals

LF020001.A12	RF020001.A12	-68	75		0.6	Al	*18*
LF020001.B12	RF020001.B12	-33	348		0.7	Al	
LF020002.B12	RF020002.B12	-57	373		0.4 x 0.7	Al	
LF020001.C12	RF020001.C12	-58	557		0.8	Al	
LF020002.C12	RF020002.C12	-51	685		0.7	Al	
LF020001.D12	RF020001.D12	-230	-18		0.5	Al	
LF020002.D12	RF020002.D12	-50	20		0.8	Al	
LF020003.D12	RF020003.D12	-135	128		1.2	Al	
LF020004.D12	RF020004.D12	-166	152		0.7	Al	
LF020005.D12	RF020005.D12	-172	108		0.5 x 0.7	Al	
LF020006.D12	RF020006.D12	-102	840		0.9	Al	
LF020007.D12	RF020007.D12	-318	930		0.5	Al	
LF020001.E12	RF020001.E12	-86	415		0.7	Al	
LF030001.F12	RF030001.F12	1330	610		1.5	Al	

Earth-Facing End Longerons and Intercostals

IMAGE FILE NAMES LEFT	IMAGE FILE NAMES RIGHT	COORDINATES (mm) X	COORDINATES (mm) Y	COORDINATES (mm) Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
AF010001.G25	BF010001.G25	-40	278	-1	0.7	Al	*d*
CF010001.G25	DF010001.G25	-40	278	-1	0.7	Al	*d*
LF020001.G25	RF020001.G25	-45	508		0.4	Al	*25*

Space-Facing End Longerons and Intercostals

IMAGE FILE NAMES LEFT	IMAGE FILE NAMES RIGHT	COORDINATES (mm) X	COORDINATES (mm) Y	COORDINATES (mm) Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LF010001.H01	RF010001.H01	-50	-68		0.5	Al	
LF020001.H01	RF020001.H01	-27	825		0.5	Al	
AF020001.H01	BF020001.H01	-27	825		0.5	Al	
CF020001.H01	DF020001.H01	-27	825		0.5	Al	
LF020002.H01	RF020002.H01	-45	545		0.5	Al	
AF020002.H01	BF020002.H01	-45	545		0.5	Al	
LF020001.H03	RF020001.H03	-35	290		0.8	Al	
LF050001.H03	RF050001.H03	63	-90		2.1	Al	
AF050001.H03	BF050001.H03	63	-90		2.1	Al	
CF050001.H03	DF050001.H03	63	-90		2.1	Al	
LF050002.H03	RF050002.H03	785	-97		0.9	Al	
LF050003.H03	RF050003.H03	610	-45		0.6	Al	
LF020001.H05	RF020001.H05	115	-4		0.6	Al	
LF020002.H05	RF020002.H05	515	-37		0.6	Al	
LF050001.H06	RF050001.H06	-12	860		0.5	Al	*14,d*
LF050002.H06	RF050002.H06	-55	655		0.8	Al	*14*
LF010001.H07	RF010001.H07	60	-18		1.0	Al	*v*
LF020001.H07	RF020001.H07	-10	75		0.8	Al	*v*
LF020002.H07	RF020002.H07	-110	120		0.5	Al	*v*
LF030001.H07	RF030001.H07	830	800		0.9	Al	*17,d*
LF050001.H09	RF050001.H09	800	85		0.5	Al	
LF010001.H12	RF010001.H12	2	-17		0.6	Al	
LF010001.H18	RF010001.H18	130	200		0.6	Al	*14*
LF010002.H18	RF010002.H18	-15	0		0.9	Al	*15*
AF010002.H18	BF010002.H18	-15	0		0.9	Al	*15*
LF010003.H18	RF010003.H18	460	85		1.8	Al	*14*
LF010001.H19	RF010001.H19	176	0		0.5	Al	*13*
LF010001.H25	RF010001.H25	-50	640		0.7	Al	
LF020001.H25	RF020001.H25	705	-65		0.6	Al	
AF020001.H25	BF020001.H25	705	-65		0.6	Al	
LF030001.H25	RF030001.H25	935	815		0.7	Al	
AF030001.H25	BF030001.H25	935	815		0.7	Al	
LF030002.H25	RF030002.H25	915	913		0.7	Al	
AF030002.H25	BF030002.H25	915	913		0.7	Al	
LF040001.H25	RF040001.H25	710	945		0.5	Al	

Space-Facing End Center Plate

IMAGE FILE NAMES LEFT	IMAGE FILE NAMES RIGHT	COORDINATES (mm) X	COORDINATES (mm) Y	COORDINATES (mm) Z	ESTIMATED DIAMETER (mm)	MATERIAL TYPE	COMMENTS
LE000001.H25	RE000001.H25	917	417		0.8	Al	
AE000001.H25	BE000001.H25	917	417		0.8	Al	
CE000001.H25	DE000001.H25	917	417		0.8	Al	
LE000002.H25	RE000002.H25	920	485		0.8	Al	
LE000003.H25	RE000003.H25	665	100		0.5	Al	

IMAGE FILE NAMES		COORDINATES (mm)			ESTIMATED	MATERIAL	
LEFT	RIGHT	X	Y	Z	DIAMETER (mm)	TYPE	COMMENTS
LE000004.H25	RE000004.H25	480	60		0.6	Al	
LE000005.H25	RE000005.H25	205	185		1.6	Al	
LE000006.H25	RE000006.H25	150	255		1.0	Al	
LE000008.H25	RE000008.H25	105	833		0.6	Al	
AE000008.H25	BE000008.H25	105	883		0.6	Al	
LE000009.H25	RE000009.H25	185	872		0.9	Al	
AE000009.H25	BE000009.H25	185	872		0.9	Al	
CE000009.H25	DE000009.H25	185	872		0.9	Al	
EE000009.H25	FE000009.H25	185	872		0.9	Al	
LE000010.H25	RE000010.H25	225	811		0.7	Al	
LE000011.H25	RE000011.H25	375	922		0.8	Al	
LM000001.M00	RM000001.M00	0	0		1.2	micrometer	*n*
LM000002.M00	RM000002.M00	0	0		2.4	micrometer	*o*
LM000003.M00	RM000003.M00	0	0		4.9	micrometer	*p*
LM000004.M00	RM000004.M00	0	0		9.7	micrometer	*q*

1 - Ejecta spray pattern from an impact on an adjacent experiment-tray clamp.
2 - Wrong coordinates (X = 1265, Y = -56) input into image file.
3 - Wrong coordinates (X = -120, Y = 660) input into image file.
4 - Ejecta spray pattern from an impact on an adjacent experiment-tray flange.
5 - Wrong Y-coordinate (Y = -60) input into image file.
6 - These images are incorrectly labeled feature #7 (*i.e.*, LF010007, etc.).
7 - These images are incorrectly labeled feature #8 (*i.e.*, LF010008, etc.).
8 - These images are incorrectly labeled feature #9 (*i.e.*, LF010009, etc.).
9 - Image taken at ~5° from the normal to the feature.
10 - Only an impact ejecta pattern was observed and imaged.
11 - Wrong X-coordinate (X = 100) input into image file.
12 - This is an impact feature located on an inside-facing frame member of the LDEF.
13 - Image rotated ~35° clockwise.
14 - Image rotated ~5° clockwise.
15 - Possible low-velocity impact feature.
16 - Possible oblique impact.
17 - Image rotated ~17° clockwise.
18 - Left (L) and right (R) images are switched.
19 - There may be ejecta from this impact on the adjacent experiment-tray clamp.
20 - There may be ejecta from this impact on the adjacent experiment-tray flange of tray C11.
21 - Image taken ~30° from the normal.
22 - Image F010001 and F010002 are of the same impact feature (F010001).
23 - An additional, small impact feature is visible in the image field.
24 - This is an ejecta spray pattern from an impact on an adjacent experiment-tray flange of tray B07.
25 - Group of four small features; given diameter is of the largest (may be a man-made feature).
26 - Wrong coordinates (X = -117, Y = 660) input into image file.
27 - Wrong coordinates (X = -62, Y = 565) input into image file.
28 - Wrong Feature Number (0001) input into image file.
29 - Wrong coordinates (X = -48, Y = 675) input into image file.
30 - Wrong coordinates (X = 445, Y = -50) input into image file.
31 - Wrong Y-coordinates (Y = 110) input into image file.
32 - Wrong Y-coordinates (Y = -48) input into image file.
33 - Wrong Y-coordinates (Y = -46) input into image file.
34 - Wrong Y-coordinates (Y = -140) input into image file.
35 - Wrong X-coordinates (X = -125) input into image file.

36 - Wrong X-coordinates (X = 465) input into image file.

OTHER PHOTODOCUMENTATION:

Pre-Flight
On-Orbit
Pre-Deintegration
Post Deintegration
M&D SIG Photos: S90-43581, S90-43505 through S90-43509, S90-43588, S90-43589, S90-43594 through S90-43596, S90-43516, S90-43574 through S90-43577, S90-43580 through S90-43582, S90-43585, S90-43586, S90-43594, S90-43429, S90-43435.

ARCHIVED MATERIALS:

Intercostals - B06F02, B11F02, C03F02, E05F02, E09F02, E10F02, F07F02, F08F02, and F09F02
Tape Lifts of Impact Features - LD-65 (A07F01,2)
LD-57 (A08F01,2)
LD-81 (A09F01,7)
LD-76 (A10F01,2)
LD-75 (A11F02,2)
LD-46 (A12F01,2)
LD-47 (A12F01,3)
LD-61, LD-84, LD-85 (B06F01,3)
LD-56, LD-66 (B07F01,3)
LD-42 (B11F01,2)
LD-31 (B11F02,2)
LD-60 (C05F01,1)
LD-82 (C09F01,11)
LD-77 (C10F01,1)
LD-78 (C10F01,3)
LD-43 (C11F01,3)
LD-68 (D06FO2,2)
LD-58 (D08F02,4)
LD-59 (D08F02,8)
LD-44 (D12F01,3)
LD-45 (D12F01,6)
LD-69 (E05F01,1)
LD-70 (E05F02,1)
LD-62 (E06F01,1)
LD-53 (E08F01,1)
LD-54 (E08F01,4)
LD-55 (E08F01,5)
LD-52 (E08F02,1)
LD-83 (E09F02,6)
LD-73 (E10F01,4)
LD-72 (E10F02,2)
LD-79 (E10F02,8)
LD-64 (F01F01,2)
LD-71 (F05F01,4)
LD-63 (F07F02,2)
LD-67 (F07F03,2)
LD-80 (F08F03,5)
LD-74 (F10F01,3)
LD-48 (G25F01,1)

ARCHIVED MATERIALS: (continued)

LD-50 (H05F02,2)
LD-49 (H07F03,1)

GENERAL COMMENTS LIST FOR ALL SUMMARY REPORTS

a	Rings around impact feature.
b	Impact feature with front surface spall zone.
c	Impact associated delamination zone.
d	Ejecta spray partially around crater on same surface as crater.
e	Ejecta spray onto adjacent material not co-planar with cratered surface.
f	Impact feature located on tray wall.
g	Impact located on bottom tray surface.
h	Back surface bulged.
i	Back surface spalled.
j	Multi-crater impact event.
k	Apparent material inclusions in impact feature.
l	Secondary craters.
m	Extended fracture zone around impact feature.
n	Magnification = 1.2, field of view = ~9.7 mm.
o	Magnification = 2.4, field of view = ~4.9 mm.
p	Magnification = 5.0, field of view = ~2.4 mm.
q	Magnification = 10.0, field of view = ~1.2 mm.
v	Image rotated 45° clockwise.
w	Image rotated 90° clockwise.
x	Image rotated 180°.
y	Image rotated 45° counter-clockwise.
z	Image rotated 90° counter-clockwise.

3.D SUMMARY INDEX

SECTION 4

EQUIPMENT STATUS AND CURATION

4.A. EQUIPMENT STATUS

At the completion of LDEF deintegration activities at KSC, the three surveying stereo-microscopes and three coordinate registration systems were divided among three NASA centers to facilitate further surveying of LDEF surfaces. Stereo-microscope System #1 was sent to the Marshall Space Flight Center, Stereo-Microscope and Coordinate Registration Systems #2 were sent to Langley Research Center, and Stereo-Microscope System #3 and Coordinate Registration Systems #1 and #3 reside at the Johnson Space Center.

4.B. SAMPLE CURATION

4.B.1. Introduction

A principal goal of the Meteoroid and Debris Special Investigation Group (M&D SIG) is to further detailed research into the nature of particulates in low-Earth orbit, and the effects of their impact onto spacecraft materials. Towards this goal, we have carefully selected a large variety of space-exposed materials from LDEF containing impact features, and returned them to the Curatorial Facility at the Johnson Space Center (JSC). LDEF surfaces thereby join lunar samples, Antarctic meteorites, cosmic dust, and surfaces from the Solar Maximum and Palapa spacecraft as an additional source of extraterrestrial materials for scientific study. In addition, investigators wishing to characterize the type and amount of spacecraft debris will find materials of interest that can be utilized to address these goals.

4.B.2. Sample Handling

Before shipping to JSC, each sample was encapsulated in a clean, airtight container. All experiment-tray clamps were encapsulated in dedicated Fluoroware bowls and vacuum-sealed within polyethylene bags. All blanket materials were secured within specially constructed lexan boxes, flushed with dry nitrogen, and vacuum-sealed within two nested polyethylene bags (see Section 2.E.4.f). In most cases, blankets were secured within these boxes using the same velcro that had secured them to their original LDEF trays. Most of the other LDEF samples were secured within specially constructed Teflon bags with Kapton tape. In instances where specific impact features could have been damaged either by abrasion or contamination, they were covered with specially manufactured feature-protection devices. Such a device consisted of a thin section of Viton tubing with a clear lexan window secured to one end, and double-sticky tape on the opposite end where it attached to the LDEF surface. These feature-protection devices will remain over the impact features during curation to minimize the possibility of sample modification.

4.B.3. Sample Storage and Curation

All samples were shipped to JSC, where they have been stored in the Facility for the Optical Inspection of Large Surfaces (FOILS Lab) and the Tool Control Laboratory (a dedicated storage facility). The FOILS Lab is a dedicated facility for the storage and preliminary examination of space-exposed surfaces, and occupies class 10,000 clean room. The cleanliness of this facility thus exceeds that provided by the class 100,000 clean room used to house the LDEF during integration and deintegration activities. The heart of the FOILS Lab is a Mann Comparator, which is an exceedingly stable, large platform permitting the optical scanning and documentation of large space-exposed surfaces. It is on the Mann Comparator that all thermal blankets and louvers returned from the Solar Maximum and Palapa spacecraft were initially documented. It is our intention to scan all appropriate curated LDEF surfaces on the Mann Comparator to describe smaller features than those documented by the M&D SIG at KSC during LDEF deintegration activities. Towards this end, we are in the process of upgrading and further automating the FOILS Lab at JSC.

The lists at the end of this section contains all LDEF hardware received at JSC for curation by August, 1990. Most of these materials were obtained directly from the Principle Investigators (PIs) and the LDEF Project Office during LDEF deintegration at KSC. A few additional samples have arrived since this time, having been donated or loaned by the original experiment PI. We expect that more materials will be added to the curated

materials list as time progresses. Updated listings of these materials can be obtained from the LDEF Curator (see address below).

4.B.4. Sample Requests

All of the LDEF surfaces obtained by the M&D SIG for curation described below are or will soon be, available for allocation to qualified investigators. Each of these samples remains the property of NASA and/or the original LDEF PI, and its study is conditional upon regulations embodied in various memoranda between the original LDEF PI and NASA. One universal requirement covering the study of any LDEF surface is that all data obtained will be published in the open literature and also provided to the M&D SIG for entry into the LDEF M&D SIG database. All sample allocations will be made for a period of up to two years, with the samples returning to the JSC Curatorial Facility at the end of this time.

Scientists desiring to perform detailed research on samples described in this catalog should apply in writing to:

Curator/LDEF Surfaces
Code SN2
NASA/Johnson Space Center
Houston, Texas 77058
U.S.A.

Sample requests should refer to specific sample-identification numbers and should describe the research being proposed as well as the qualifications and facilities of the investigator making the request. NASA will arrange for a review of the scientific merits of each request and will inform the requester of the results. Approval of a sample request does not imply or include funding for the proposed research. Although foreign scientists are welcome to request samples, NASA cannot provide funds to be spent outside the U.S.A. by citizens of other countries.

4.B.5. Tabulation Of LDEF Surfaces Curated By The M&D SIG

The two tables presented below together tabulate and describe the LDEF surfaces available for study. The first table lists the "Core Inventory" while the second tabulates the "Primary Surface Inventory" The specialized terminology used in these tables is explained in the following paragraphs.

A "core" is a small, separated piece of surface that has been removed from the original surface because it contained a known, specific impact feature. An example of a core would be a one-inch diameter circle of aluminum cut from a larger aluminum plate because it contains a notable impact feature. All of these core samples are thus smaller, dissected pieces of hardware. Given for each core are (1) the "Surface Name", (2) the "Feature (impact feature) Number", (3) the "Layer Number" (where appropriate, *i.e.* where a single impact event has affected more than one layer of a multi-layer substrate), (4) a brief description of the impact substrate, and (5) the "Core Number". These headings are more fully explained immediately below.

The Surface Name, "Primary Surface Name", or Surface is a six-character alphanumeric designation for each LDEF experiment surface. The first three characters give the tray location (*e.g.,* A01 would be Bay A on Row 01). The fourth character is always a letter designation for the type of surface, called a "Component". These Component abbreviations are

E - Main surface of the experiment.
F - Frame member of an experiment tray or the LDEF structure.
S - Screw or bolt.
C - Clamp for an experiment or grapple-fixture tray.
H - Shim associated with a clamp.
R - Reflector.

The final two numbers in each Surface Name give the number of the specific surface. Thus, the Surface Name A05C03 would indicate clamp number 03 from experiment Bay A on Row 05. See Section 2.C for a detailed description of the nomenclature scheme adopted by the M&D SIG.

The Feature Number is the numeric designation of an impact feature, as assigned during the course of documentation of the LDEF experiment surface. For example, Feature Number 4 from Surface Number A01E00 (the first entry in the table below) was the fourth impact feature documented for surface E00 of tray A01. Only a limited selection of the approximately 5000 impact features documented at KSC were acquired for curation and further examination (and inclusion in this catalog).

The Layer Number is a modifying designation applied to a piece of curated hardware if there are multiple manifestations of a given impact feature on sequential layers of a multi-layered substrate. The most common example on LDEF is an impact feature that penetrated more then one layer of a multi-layered, aluminized Mylar thermal blanket. The lowest Layer Number for a given impact feature is generally the outermost penetrated layer, and the highest number is the innermost layer on which deformation from the impactor was noted.

The Core Number is the alternate designation given to each curated piece of LDEF hardware during curatorial processing, and need not be cited in publications or sample requests.

"Kapton Tape Lifts" were made of numerous impact features on the LDEF frame members. This seemed to be the only way to sample these features for projectile residue material, given that most LDEF frame members could not be removed individually for analysis. Not all tape-lift attempts appeared to be successful, but all were curated in the hope that apparently unsuccessful lifts might contain unobserved, but significant amounts of analyzable material.

Table 2 also lists the physical location of each curated sample as of August, 1990. Most samples are in the FOILS and Tool Control laboratories. These are specific designations for Curatorial facilities at JSC, and these samples are thus available for allocation. Some samples have already been distributed to investigators, and in these instances the appropriate PI's name is indicated.

TABLE 1
LDEF CORE INVENTORY

SURFACE NAME	FEATURE NUMBER	LAYER NUMBER	BRIEF DESCRIPTION OF IMPACT SUBSTRATE	CORE NUMBER (CURATORIAL #)	LOCATION AND COMMENTS
A01E00,	4		Graphite Composite	LD-114	FOILS
A01E00,	5		Graphite Composite	LD-113	FOILS
A01E00,	8		Graphite Composite	LD-115	FOILS
A01E00,	9		Graphite Composite	LD-116	FOILS
A07E00,	8		Graphite Composite	LD-117	FOILS
A07E00,	14		Graphite Composite	LD-118	FOILS
A07E00,	17		Graphite Composite	LD-119	FOILS
A07F01,	2		Tape Lift	LD-65	FOILS
A08F01,	2		Tape Lift	LD-57	FOILS
A09F01,	7		Tape Lift	LD-81	FOILS
A10F01,	2		Tape Lift	LD-76	FOILS
A11F02,	2		Tape Lift	LD-75	FOILS
A12F01,	2		Tape Lift	LD-46	FOILS
A12F01,	3		Tape Lift	LD-47	FOILS
B06F01,	3		Tape Lift	LD-61	FOILS
B06F01,	3		Tape Lift	LD-84	FOILS
B06F01,	3		Tape Lift	LD-85	FOILS
B07F01,	3		Tape Lift	LD-56	FOILS
B07F01,	3		Tape Lift	LD-66	FOILS
B11F01,	2		Tape Lift	LD-42	FOILS
B11F02,	2		Tape Lift	LD-41	FOILS
C05F01,	1		Tape Lift	LD-60	FOILS
C09F01,	11		Tape Lift	LD-82	FOILS
C10F01,	1		Tape Lift	LD-77	FOILS
C10F01,	3		Tape Lift	LD-78	FOILS
C11F01,	3		Tape Lift	LD-43	FOILS
D05E00,	15		Copper Foil	LD-32	FOILS
D05E01,	15		Copper Ground Strap	LD-87	FOILS
D06F02,	2		Tape Lift	LD-68	FOILS
D08F02,	4		Tape Lift	LD-58	FOILS
D08F02,	8		Tape Lift	LD-59	FOILS
D10E01,	1		Al-Mylar Foil	LD-22	FOILS
D10E01,	2		Al-Mylar Foil	LD-22	FOILS
D10E01,	3	1	Al-Mylar Foil	LD-17	FOILS
D10E01,	3	2	Al-Mylar Foil	LD-18	FOILS
D12F01,	3		Tape Lift	LD-44	FOILS
D12F01,	6		Tape Lift	LD-45	FOILS
E05F01,	1		Tape Lift	LD-69	FOILS
E05F02,	1		Tape Lift	LD-70	FOILS
E06F01,	1		Tape Lift	LD-62	FOILS
E08F01,	1		Tape Lift	LD-53	FOILS
E08F01,	4		Tape Lift	LD-54	FOILS
E08F01,	5		Tape Lift	LD-55	FOILS
E08F02,	1		Tape Lift	LD-52	FOILS
E09F02,	6		Tape Lift	LD-83	FOILS
E10F01,	4		Tape Lift	LD-73	FOILS
E10F02,	2		Tape Lift	LD-72	FOILS
E10F02,	8		Tape Lift	LD-79	FOILS
E12E00,	4		White-Painted Aluminum	LD-5	FOILS

SURFACE NAME	FEATURE NUMBER	LAYER NUMBER	BRIEF DESCRIPTION OF IMPACT SUBSTRATE	CORE NUMBER (CURATORIAL #)	LOCATION AND COMMENTS
E12E00,	5		White-Painted Aluminum	LD-6	FOILS
E12E00,	6		White-Painted Aluminum	LD-7	FOILS
E12E00,	7		Aluminum	LD-8	FOILS
E12E00,	8		White-Painted Aluminum	LD-4	FOILS, Bolt + Washer
E12E00,	16		White-Painted Aluminum	LD-3	FOILS
E12F01,	2		Tape Lift	LD-51	FOILS
E12S01,	8		Steel Screw	LD-2	
F01F01,	2		Tape Lift	LD-64	FOILS
F05F01,	4		Tape Lift	LD-71	FOILS
F07F02,	2		Tape Lift	LD-63	FOILS
F07F03,	2		Tape Lift	LD-67	FOILS
F08F03,	5		Tape Lift	LD-80	FOILS
F09E00,	31		Aluminum Tape	LD-33	FOILS, Tape Over Screw
F09E00,	31		Steel Bolt	LD-35	FOILS, Screw Under Tape
F09E01,	7		Al-Mylar Foil	LD-27	FOILS
F09E01,	16	1	Al-Mylar Foil	LD-28	FOILS
F09E01,	16	2	Al-Mylar Foil	LD-29	FOILS
F09E01,	16	3	Al-Mylar Foil	LD-30	FOILS
F09E05,	19		Multi-layered Blanket	LD-31	FOILS
F09E08,	1		Multi-layered Blanket	LD-36	FOILS
F09E08,	2		Multi-layered Blanket	LD-37	FOILS
F09E08,	14		Multi-layered Blanket	LD-38	FOILS
F09E08,	24		Multi-layered Blanket	LD-39	FOILS
F09E08,	25		Multi-layered Blanket	LD-86	FOILS
F09E08,	27		Multi-layered Blanket	LD-39	FOILS
F10F01,	3		Tape Lift	LD-74	FOILS
F12E01,	15		Al-Mylar Foil	LD-19	FOILS
F12E01,	17		Al-Mylar Foil	LD-20	FOILS
F12E02,	1		Al Foil	LD-15	FOILS
F12E02,	2		Al-Mylar Foil	LD-25	FOILS
F12E02,	3		Al-Mylar Foil	LD-26	FOILS
F12E02,	4		Al-Mylar Foil	LD-24	FOILS
F12E02,	5		Al-Mylar Foil	LD-23	FOILS
F12E03,	1		Al Tape	LD-16	FOILS
F12E03,	2		Al Tape	LD-16	FOILS
G25F01,	1		Tape Lift	LD-48	FOILS
H03E00,	13	2	Lexan Sheet	LD-98	FOILS
H03E00,	13	3	Lexan Sheet	LD-99	FOILS
H03E00,	13	4	Lexan Sheet	LD-100	FOILS
H03E00,	13	5	Lexan Sheet	LD-101	FOILS
H03E00,	14	2	Lexan Sheet	LD-95	FOILS
H03E00,	14	3	Lexan Sheet	LD-96	FOILS
H03E00,	14	4	Lexan Sheet	LD-97	FOILS
H03E00,	15	2	Lexan Sheet	LD-88	FOILS
H03E00,	15	3	Lexan Sheet	LD-89	FOILS
H03E00,	15	4	Lexan Sheet	LD-90	FOILS
H03E00,	15	5	Lexan Sheet	LD-91	FOILS
H03E00,	15	6	Lexan Sheet	LD-92	FOILS
H03E00,	15	7	Lexan Sheet	LD-93	FOILS
H03E00,	15	8	Lexan Sheet	LD-94	FOILS
H05F02,	2		Tape Lift	LD-50	FOILS

SURFACE NAME	FEATURE NUMBER	LAYER NUMBER	BRIEF DESCRIPTION OF IMPACT SUBSTRATE	CORE NUMBER (CURATORIAL #)	LOCATION AND COMMENTS
H07F03,	1		Tape Lift	LD-49	FOILS
H09E00,	3		White-Painted Aluminum	LD-10	FOILS
H09E00,	7		White-Painted Aluminum	LD-11	FOILS
H09E00,	8		White-Painted Aluminum	LD-12	FOILS
H09E00,	9		White-Painted Aluminum	LD-13	FOILS
H09E00,	10		White-Painted Aluminum	LD-9	FOILS
H12E00,	1	2	Lexan Sheet	LD-102	FOILS
H12E00,	1	3	Lexan Sheet	LD-103	FOILS
H12E00,	1	4	Lexan Sheet	LD-104	FOILS
H12E00,	1	5	Lexan Sheet	LD-105	FOILS
H12E00,	1	6	Lexan Sheet	LD-106	FOILS
H12E00,	1	7	Lexan Sheet	LD-107	FOILS
H12E00,	1	8	Lexan Sheet	LD-108	FOILS
H12E00,	1	9	Lexan Sheet	LD-109	FOILS
H12E00,	1	10	Lexan Sheet	LD-110	FOILS
H12E00,	1	11	Lexan Sheet	LD-111	FOILS
H12E00,	1	12	Lexan Sheet	LD-112	FOILS
H12E00,	8		Al Tape Over Screw	LD-21	FOILS

TABLE 2
LDEF PRIMARY SURFACE INVENTORY

SURFACE	COMPONENT	MATERIAL	LOCATION AND COMMENTS
A01C01	Clamp	Aluminum	FOILS
A01C03	Clamp	Aluminum	FOILS
A01C04	Clamp	Aluminum	FOILS
A01C08	Clamp	Aluminum	FOILS
A01E00	Experiment Tray	Aluminum	JSC - Bldg 420
A01S01B	Bolt	Steel	FOILS - Box 01
A02C01	Clamp	Aluminum	FOILS
A02C03	Clamp	Aluminum	FOILS
A02C05	Clamp	Aluminum	FOILS
A02C06	Clamp	Aluminum	FOILS
A02S07C	Bolt	Steel	FOILS - Box 05
A02S08C	Bolt	Steel	FOILS - Box 05
A03C01	Clamp	Aluminum	FOILS
A03C03	Clamp	Aluminum	FOILS
A03C04	Clamp	Aluminum	FOILS
A03C06	Clamp	Aluminum	FOILS
A03S03B	Bolt	Steel	FOILS - Box 02
A03S07B	Bolt	Steel	FOILS - Box 02
A03S07C	Bolt	Steel	FOILS - Box 02
A04C03	Clamp	Aluminum	FOILS
A04C05	Clamp	Aluminum	FOILS
A04C06	Clamp	Aluminum	FOILS
A04C08	Clamp	Aluminum	FOILS
A04E00A	Experiment Tray	Teflon Blanket	Tool Control
A05C03	Clamp	Aluminum	FOILS
A05C06	Clamp	Aluminum	FOILS
A05C07	Clamp	Aluminum	FOILS
A05C08	Clamp	Aluminum	FOILS
A06C04	Clamp	Aluminum	FOILS
A06C05	Clamp	Aluminum	FOILS
A06C06	Clamp	Aluminum	FOILS
A06C08	Clamp	Aluminum	FOILS
A07C01	Clamp	Aluminum	FOILS
A07C03	Clamp	Aluminum	FOILS
A07C06	Clamp	Aluminum	FOILS
A07C08	Clamp	Aluminum	FOILS
A07E00	Experiment Tray	Aluminum	JSC - Bldg 420
A08C01	Clamp	Aluminum	FOILS
A08C03	Clamp	Aluminum	FOILS
A08C07	Clamp	Aluminum	FOILS
A08C08	Clamp	Aluminum	FOILS
A09C01	Clamp	Aluminum	FOILS
A09C02	Clamp	Aluminum	FOILS
A09C05	Clamp	Aluminum	FOILS
A09C06	Clamp	Aluminum	McDonnell
A10C01	Clamp	Aluminum	FOILS
A10C02	Clamp	Aluminum	FOILS
A10C06	Clamp	Aluminum	FOILS
A10C08	Clamp	Aluminum	FOILS
A10E00A	Experiment Tray	Teflon Blanket	Tool Control

SURFACE	COMPONENT	MATERIAL	LOCATION AND COMMENTS
A10H06	Shim	Aluminum	FOILS - Box 05
A10S05B	Bolt	Steel	FOILS - Box 05
A11C01	Clamp	Aluminum	FOILS
A11C05	Clamp	Aluminum	FOILS
A11C07	Clamp	Aluminum	FOILS
A11C08	Clamp	Aluminum	FOILS
A11S01A	Bolt	Steel	FOILS - Box 02
A11S02A	Bolt	Steel	FOILS - Box 02
A12C01	Clamp	Aluminum	FOILS
A12C02	Clamp	Aluminum	FOILS
A12C05	Clamp	Aluminum	FOILS
A12C06	Clamp	Aluminum	FOILS
B01C02	Clamp	Aluminum	Zolensky
B01C05	Clamp	Aluminum	Zolensky
B01C06	Clamp	Aluminum	Zolensky
B01C08	Clamp	Aluminum	Zolensky
B01S05A	Bolt	Steel	FOILS - Box 02
B01S08C	Bolt	Steel	FOILS - Box 02
B02C01	Clamp	Aluminum	Zolensky
B02C02	Clamp	Aluminum	Zolensky
B02C05	Clamp	Aluminum	Zolensky
B02C08	Clamp	Aluminum	Zolensky
B03C01	Clamp	Aluminum	Zolensky
B03C03	Clamp	Aluminum	Zolensky
B03C06	Clamp	Aluminum	Zolensky
B03C08	Clamp	Aluminum	Zolensky
B04C01	Clamp	Aluminum	Zolensky
B04C03	Clamp	Aluminum	Zolensky
B04C05	Clamp	Aluminum	Zolensky
B04C06	Clamp	Aluminum	Zolensky
B05C01	Clamp	Aluminum	Zolensky
B05C02	Clamp	Aluminum	Zolensky
B05C06	Clamp	Aluminum	Zolensky
B05C08	Clamp	Aluminum	Zolensky
B05E00A	Experiment Tray	Teflon Blanket	Tool Control
B06C03	Clamp	Aluminum	Zolensky
B06C04	Clamp	Aluminum	Zolensky
B06C06	Clamp	Aluminum	Zolensky
B06C08	Clamp	Aluminum	Zolensky
B06H07	Shim	Aluminum	FOILS - Box 05
B06S07A	Bolt	Steel	FOILS - Box 05
B06F02	Frame	Aluminum	FOILS, Intercostal
B07C01	Clamp	Aluminum	Zolensky
B07C03	Clamp	Aluminum	Zolensky
B07C06	Clamp	Aluminum	Zolensky
B07C08	Clamp	Aluminum	Zolensky
B07E00A	Experiment Tray	Teflon Blanket	Tool Control
B08C04	Clamp	Aluminum	Zolensky
B08C05	Clamp	Aluminum	Zolensky
B08C06	Clamp	Aluminum	Zolensky
B08C08	Clamp	Aluminum	Zolensky
B08E00A	Experiment Tray	White-Painted Al	Tool Control

SURFACE	COMPONENT	MATERIAL	LOCATION AND COMMENTS
B08H04	Shim	Aluminum	FOILS - Box 02, Shim Under Clamp 4
B08S01	Bolt	Steel	FOILS - Box 01, 10-32; Crater On Washer; Sprayed Material Onto White Plate
B08S02	Bolt	Steel	FOILS - Box 01, 6-24; Material Sprayed Across; Shielded Partly White Plate
B08S03	Bolt	Steel	FOILS - Box 01
B08S04	Bolt	Steel	FOILS - Box 01
B08S05	Bolt	Steel	FOILS - Box 01
B08S06	Bolt	Steel	FOILS - Box 01
B08S07	Bolt	Steel	FOILS - Box 01
B08S08	Bolt	Steel	FOILS - Box 01
B08S09	Bolt	Steel	FOILS - Box 01
B09C02	Clamp	Aluminum	Zolensky
B09C05	Clamp	Aluminum	Zolensky
B09C06	Clamp	Aluminum	McDonnell
B09C08	Clamp	Aluminum	McDonnell
B09H08	Shim	Aluminum	FOILS - Box 02, Shim Under Clamp 8
B09S01C	Bolt	Steel	FOILS - Box 02
B09S03A	Bolt	Steel	FOILS - Box 02
B09S04C	Bolt	Steel	FOILS - Box 02
B10C01	Clamp	Aluminum	Zolensky
B10C04	Clamp	Aluminum	Zolensky
B10C06	Clamp	Aluminum	Zolensky
B10C07	Clamp	Aluminum	Zolensky
B10S03C	Bolt	Steel	FOILS - Box 02
B10S04A	Bolt	Steel	FOILS - Box 02
B10S04C	Bolt	Steel	FOILS - Box 02
B10S06B	Bolt	Steel	FOILS - Box 02
B10S08B	Bolt	Steel	FOILS - Box 02
B11C04	Clamp	Aluminum	Zolensky
B11C06	Clamp	Aluminum	Zolensky
B11C07	Clamp	Aluminum	Zolensky
B11C08	Clamp	Aluminum	Zolensky
B11F02	Frame	Aluminum	FOILS, Intercostal
B11S01A	Bolt	Steel	FOILS - Box 02
B11S07A	Bolt	Steel	FOILS - Box 02
B12C01	Clamp	Aluminum	Zolensky
B12C02	Clamp	Aluminum	Zolensky
B12C05	Clamp	Aluminum	Zolensky
B12C06	Clamp	Aluminum	Zolensky
B12S03B	Bolt	Steel	FOILS - Box 02
C01C03	Clamp	Aluminum	FOILS
C01C04	Clamp	Aluminum	Zolensky
C01C06	Clamp	Aluminum	FOILS
C01C08	Clamp	Aluminum	FOILS
C01E01	Experiment Tray	Teflon/Nylon	FOILS - Box 01, End Button Off Grappling Fixture

SURFACE	COMPONENT	MATERIAL	LOCATION AND COMMETS
C02C03	Clamp	Aluminum	FOILS
C02C04	Clamp	Aluminum	FOILS
C02C05	Clamp	Aluminum	FOILS
C02C08	Clamp	Aluminum	FOILS
C02E02	Experiment Tray	Mirror	FOILS - Box 07, Laser Mirror
C02E03	Experiment Tray	Mirror	FOILS - Box 07, CVI Mirror
C02E04	Experiment Tray	Exp. Surface	FOILS - Box 07
C02E05	Experiment Tray	Mirror	FOILS - Box 07, Fused Silica
C02E06	Experiment Tray	Mirror	FOILS - Box 07, Be Mirror
C02E07	Experiment Tray	Aluminum	FOILS
C03C01	Clamp	Aluminum	FOILS - Box 03
C03C04	Clamp	Aluminum	Zolensky
C03C05	Clamp	Aluminum	FOILS - Box 03
C03C08	Clamp	Aluminum	Zolensky
C03F02	Frame	Aluminum	FOILS, Intercostal
C04C03	Clamp	Aluminum	FOILS
C04C04	Clamp	Aluminum	Zolensky
C04C06	Clamp	Aluminum	FOILS
C04C08	Clamp	Aluminum	Zolensky
C05C03	Clamp	Aluminum	FOILS
C05C04	Clamp	Aluminum	Zolensky
C05C07	Clamp	Aluminum	FOILS
C05C08	Clamp	Aluminum	FOILS
C05E00A	Experiment Tray	Teflon Blanket	Tool Control
C05H07	Shim	Aluminum	FOILS - Box 02
C06C04	Clamp	Aluminum	FOILS
C06C06	Clamp	Aluminum	FOILS
C06C07	Clamp	Aluminum	FOILS
C06C08	Clamp	Aluminum	FOILS
C06E00A	Experiment Tray	Teflon Blanket	Tool Control
C07C03	Clamp	Aluminum	FOILS
C07C04	Clamp	Aluminum	Zolensky
C07C05	Clamp	Aluminum	FOILS
C07C08	Clamp	Aluminum	Zolensky
C08C02	Clamp	Aluminum	FOILS
C08C03	Clamp	Aluminum	FOILS
C08C04	Clamp	Aluminum	FOILS
C08C06	Clamp	Aluminum	FOILS
C08E00A	Experiment Tray	Teflon Blanket	Tool Control
C08S01A	Bolt	Steel	FOILS - Box 02
C08S03B	Bolt	Steel	FOILS - Box 02
C09C03	Clamp	Aluminum	FOILS - Box 03
C09C04	Clamp	Aluminum	Zolensky
C09C05	Clamp	Aluminum	FOILS - Box 03
C09C08	Clamp	Aluminum	Zolensky
C09H03	Shim	Aluminum	FOILS - Box 03
C09S06A	Bolt	Steel	FOILS - Box 02
C09S07B	Bolt	Steel	FOILS - Box 02
C09S07C	Bolt	Steel	FOILS - Box 02
C10C02	Clamp	Aluminum	FOILS
C10C04	Clamp	Aluminum	Zolensky
C10C05	Clamp	Aluminum	FOILS

SURFACE	COMPONENT	MATERIAL	LOCATION AND COMMENTS
C10C06	Clamp	Aluminum	FOILS
C10E01	Experiment Tray	Teflon/Nylon	FOILS - Box 01, End Button Off Grappling Fixture
C11C01	Clamp	Aluminum	FOILS
C11C02	Clamp	Aluminum	FOILS
C11C04	Clamp	Aluminum	FOILS
C11C08	Clamp	Aluminum	FOILS
C11E00A	Experiment Tray	Teflon Blanket	Tool Control
C12C01	Clamp	Aluminum	FOILS
C12C02	Clamp	Aluminum	FOILS
C12C03	Clamp	Aluminum	FOILS
C12C08	Clamp	Aluminum	Zolensky
C12E00A	Experiment Tray	Painted Plastic	FOILS
C12S02A	Bolt	Steel	FOILS - Box 05
D01C02	Clamp	Aluminum	Zolensky
D01C05	Clamp	Aluminum	FOILS
D01C06	Clamp	Aluminum	FOILS
D01C08	Clamp	Aluminum	Zolensky
D01E00A	Experiment Tray	Teflon Blanket	Tool Control
D02C02	Clamp	Aluminum	FOILS
D02C04	Clamp	Aluminum	Zolensky
D02C06	Clamp	Aluminum	Zolensky
D02C08	Clamp	Aluminum	Zolensky
D03C06	Clamp	Aluminum	Zolensky
D03C08	Clamp	Aluminum	FOILS
D04C02	Clamp	Aluminum	FOILS
D04C03	Clamp	Aluminum	FOILS
D04C05	Clamp	Aluminum	FOILS
D04C07	Clamp	Aluminum	FOILS
D05C04	Clamp	Aluminum	Zolensky
D05C05	Clamp	Aluminum	Zolensky
D05C07	Clamp	Aluminum	Zolensky
D05C08	Clamp	Aluminum	FOILS
D05E00A	Experiment Tray	Teflon Blanket	Tool Control
D05E01	Connector	Al Ground Strap	FOILS - Box 06
D05S06B	Bolt	Steel	FOILS - Box 05
D06C03	Clamp	Aluminum	FOILS
D06C04	Clamp	Aluminum	Zolensky
D06C05	Clamp	Aluminum	Zolensky
D06C08	Clamp	Aluminum	Zolensky
D06S04A	Bolt	Steel	FOILS - Box 01
D06S04C	Bolt	Steel	FOILS - Box 01
D06S06A	Bolt	Steel	FOILS - Box 01
D07C03	Clamp	Aluminum	FOILS
D07C04	Clamp	Aluminum	Zolensky
D07C05	Clamp	Aluminum	Zolensky
D07C07	Clamp	Aluminum	Zolensky
D07E00A	Experiment Tray	Teflon Blanket	Tool Control
D07H06	Shim	Aluminum	FOILS - Box 02
D08C01	Clamp	Aluminum	Zolensky
D08C04	Clamp	Aluminum	Zolensky
D08C05	Clamp	Aluminum	Zolensky
D08S06A	Bolt	Steel	FOILS - Box 02

SURFACE	COMPONENT	MATERIAL	LOCATION AND COMMENTS
D09C03	Clamp	Aluminum	FOILS
D09C04	Clamp	Aluminum	Zolensky
D09C07	Clamp	Aluminum	Zolensky
D09S04A	Bolt	Steel	FOILS - Box 02
D10C03	Clamp	Aluminum	Zolensky
D10C07	Clamp	Aluminum	Zolensky
D10C08	Clamp	Aluminum	Zolensky
D10S03C	Bolt	Steel	FOILS - Box 02
D10S05B	Bolt	Steel	FOILS - Box 02
D11C03	Clamp	Aluminum	Zolensky
D11C04	Clamp	Aluminum	Zolensky
D11C05	Clamp	Aluminum	FOILS
D11E00A	Experiment Tray	Teflon Blanket	Tool Control
D11S01A	Bolt	Steel	FOILS - Box 02
D12C01	Clamp	Aluminum	FOILS
D12C02	Clamp	Aluminum	FOILS
D12C04	Clamp	Aluminum	FOILS
D12C05	Clamp	Aluminum	FOILS
E01C01	Clamp	Aluminum	FOILS
E01C02	Clamp	Aluminum	FOILS
E01C04	Clamp	Aluminum	Zolensky
E01C06	Clamp	Aluminum	FOILS
E01H01	Shim	Aluminum	FOILS - Box 02, Shim Under Clamp 1
E01S01C	Bolt	Steel	FOILS - Box 02
E02C01	Clamp	Aluminum	FOILS
E02C02	Clamp	Aluminum	FOILS
E02C04	Clamp	Aluminum	Zolensky
E02C05	Clamp	Aluminum	FOILS
E02E00A	Experiment Tray	Teflon Blanket	FOILS
E03C02	Clamp	Aluminum	FOILS
E03C04	Clamp	Aluminum	Zolensky
E03C05	Clamp	Aluminum	FOILS
E03C07	Clamp	Aluminum	FOILS
E04C01	Clamp	Aluminum	FOILS
E04C03	Clamp	Aluminum	FOILS
E04C04	Clamp	Aluminum	Zolensky
E04C08	Clamp	Aluminum	Zolensky
E05C03	Clamp	Aluminum	FOILS
E05C04	Clamp	Aluminum	Zolensky
E05C05	Clamp	Aluminum	FOILS
E05C07	Clamp	Aluminum	FOILS
E05E01	Experiment Tray	Sunscreen	FOILS, Position 4
E05E02	Experiment Tray	Sunscreen	FOILS, Position 3
E05F02	Frame	Aluminum	FOILS, Intercostal
E06C02	Clamp	Aluminum	FOILS
E06C04	Clamp	Aluminum	FOILS
E06C05	Clamp	Aluminum	FOILS
E06C07	Clamp	Aluminum	FOILS
E06E00A	Experiment Tray	Al-Mylar Blanket	FOILS, Blanket
E06S08B	Bolt	Steel	FOILS - Box 01
E07C02	Clamp	Aluminum	FOILS
E07C03	Clamp	Aluminum	FOILS

SURFACE	COMPONENT	MATERIAL	LOCATION AND COMMENTS
E07C05	Clamp	Aluminum	FOILS
E07C07	Clamp	Aluminum	FOILS
E07S04B	Bolt	Steel	FOILS - Box 05
E08C02	Clamp	Aluminum	FOILS
E08C04	Clamp	Aluminum	Zolensky
E08C05	Clamp	Aluminum	FOILS
E08C07	Clamp	Aluminum	FOILS
E08S04A	Bolt	Steel	FOILS - Box 02
E09C01	Clamp	Aluminum	FOILS
E09C05	Clamp	Aluminum	FOILS
E09C07	Clamp	Aluminum	FOILS
E09C08	Clamp	Aluminum	Zolensky
E09S05C	Bolt	Steel	FOILS - Box 02
E09S07C	Bolt	Steel	FOILS - Box 02
E09F02	Frame	Aluminum	FOILS, Intercostal
E10C01	Clamp	Aluminum	FOILS
E10C05	Clamp	Aluminum	FOILS
E10C07	Clamp	Aluminum	FOILS
E10C08	Clamp	Aluminum	Zolensky
E10E00A	Experiment Tray	Teflon Blanket	Tool Control
E10E01	Experiment Tray	Al Ground Strap	FOILS - Box 06
E10F02	Frame	Aluminum	FOILS, Intercostal
E10S05C	Bolt	Steel	FOILS - Box 05
E11C01	Clamp	Aluminum	FOILS
E11C02	Clamp	Aluminum	FOILS
E11C05	Clamp	Aluminum	FOILS
E11C08	Clamp	Aluminum	Zolensky
E11S02C	Bolt	Steel	FOILS - Box 05
E12C01	Clamp	Aluminum	FOILS
E12C03	Clamp	Aluminum	FOILS
E12C04	Clamp	Aluminum	Zolensky
E12C08	Clamp	Aluminum	Zolensky
F01C01	Clamp	Aluminum	FOILS
F01C02	Clamp	Aluminum	FOILS
F01C04	Clamp	Aluminum	FOILS
F01C05	Clamp	Aluminum	FOILS
F02C02	Clamp	Aluminum	FOILS
F02C03	Clamp	Aluminum	FOILS
F02C04	Clamp	Aluminum	FOILS
F02C07	Clamp	Aluminum	FOILS
F02E00A	Experiment Tray	Teflon Blanket	Tool Control
F02E00B	Experiment Tray	Teflon Blanket	Tool Control
F02E00C	Experiment Tray	Teflon Blanket	Tool Control
F03C01	Clamp	Aluminum	FOILS
F03C04	Clamp	Aluminum	FOILS
F03C05	Clamp	Aluminum	FOILS
F03C08	Clamp	Aluminum	FOILS
F04C01	Clamp	Aluminum	FOILS
F04C04	Clamp	Aluminum	FOILS
F04C05	Clamp	Aluminum	FOILS
F04C08	Clamp	Aluminum	FOILS
F04E00A	Experiment Tray	Teflon Blanket	Tool Control
F04H04	Shim	Aluminum	FOILS - Box 05

SURFACE	COMPONENT	MATERIAL	LOCATION AND COMMENTS
F04H06	Shim	Aluminum	FOILS - Box 05
F04S04B	Bolt	Steel	FOILS - Box 05
F05C01	Clamp	Aluminum	FOILS
F05C05	Clamp	Aluminum	FOILS
F05C06	Clamp	Aluminum	FOILS
F05C07	Clamp	Aluminum	FOILS
F05H07	Shim	Aluminum	FOILS - Box 02, Shim Under Clamp 7
F05S01B	Bolt	Steel	FOILS - Box 02
F05S01C	Bolt	Steel	FOILS - Box 02
F05S03A	Bolt	Steel	FOILS - Box 02
F05S07B	Bolt	Steel	FOILS - Box 02
F06C02	Clamp	Aluminum	FOILS
F06C05	Clamp	Aluminum	FOILS
F06C07	Clamp	Aluminum	FOILS
F06C08	Clamp	Aluminum	FOILS
F07C01	Clamp	Aluminum	FOILS
F07C04	Clamp	Aluminum	FOILS
F07C06	Clamp	Aluminum	FOILS
F07C08	Clamp	Aluminum	FOILS
F07H01	Shim	Aluminum	FOILS - Box 02, Shim Under Clamp 1
F07F02	Frame	Aluminum	FOILS, Intercostal
F08C01	Clamp	Aluminum	FOILS
F08C05	Clamp	Aluminum	FOILS
F08C07	Clamp	Aluminum	FOILS
F08C08	Clamp	Aluminum	FOILS
F08S04B	Bolt	Steel	FOILS - Box 01
F08F02	Frame	Aluminum	FOILS, Intercostal
F09C02	Clamp	Aluminum	FOILS
F09C03	Clamp	Aluminum	FOILS
F09C05	Clamp	Aluminum	FOILS
F09C07	Clamp	Aluminum	FOILS
F09E02	Experiment Tray	Al-Mylar Blanket	FOILS
F09E03	Experiment Tray	Al-Mylar Blanket	FOILS
F09E04	Experiment Tray	Al-Mylar Blanket	FOILS
F09E07	Experiment Tray	Al-Mylar Blanket	FOILS
F09F02	Frame	Aluminum	FOILS, Intercostal
F09S02A	Bolt	Steel	FOILS - Box 05
F09S04C	Bolt	Steel	FOILS - Box 05
F10C03	Clamp	Aluminum	FOILS
F10C05	Clamp	Aluminum	FOILS
F10C06	Clamp	Aluminum	FOILS
F10C08	Clamp	Aluminum	FOILS
F10S08A	Bolt	Steel	FOILS - Box 02
F11C02	Clamp	Aluminum	FOILS
F11C04	Clamp	Aluminum	FOILS
F11C06	Clamp	Aluminum	FOILS
F11C07	Clamp	Aluminum	FOILS
F12C02	Clamp	Aluminum	FOILS
F12C04	Clamp	Aluminum	FOILS
F12C05	Clamp	Aluminum	FOILS
F12C07	Clamp	Aluminum	FOILS

SURFACE	COMPONENT	MATERIAL	LOCATION AND COMMENTS
F12H01	Shim	Aluminum	FOILS - Box 05
F12S04C	Bolt	Steel	FOILS - Box 05
F12S07B	Bolt	Steel	FOILS - Box 05
G02C01	Clamp	Aluminum	Zolensky
G02C02	Clamp	Aluminum	FOILS
G02C06	Clamp	Aluminum	FOILS
G02C07	Clamp	Aluminum	FOILS
G02C10	Clamp	Aluminum	FOILS
G02C11	Clamp	Aluminum	FOILS
G03S01	Bolt	Steel	FOILS - Box 06
G04C03	Clamp	Aluminum	Zolensky
G04C04	Clamp	Aluminum	FOILS
G04C06	Clamp	Aluminum	FOILS
G04C07	Clamp	Aluminum	FOILS
G04C09	Clamp	Aluminum	FOILS
G04C12	Clamp	Aluminum	FOILS
G06C06	Clamp	Aluminum	FOILS
G06C07	Clamp	Aluminum	FOILS
G06C09	Clamp	Aluminum	FOILS
G06C11	Clamp	Aluminum	FOILS
G06C12	Clamp	Aluminum	FOILS
G06S04A	Bolt	Steel	FOILS - Box 02, Bolt
G08C01	Clamp	Aluminum	Zolensky
G08C03	Clamp	Aluminum	FOILS
G08C04	Clamp	Aluminum	FOILS
G08C10	Clamp	Aluminum	FOILS
G08C11	Clamp	Aluminum	FOILS
G08C12	Clamp	Aluminum	FOILS
G10C01	Clamp	Aluminum	FOILS
G10C04	Clamp	Aluminum	FOILS
G10C06	Clamp	Aluminum	FOILS
G10C08	Clamp	Aluminum	FOILS
G10C10	Clamp	Aluminum	FOILS
G10C12	Clamp	Aluminum	FOILS
G12C06	Clamp	Aluminum	Zolensky
G12C07	Clamp	Aluminum	FOILS
G12C09	Clamp	Aluminum	FOILS
G12C10	Clamp	Aluminum	FOILS
G12C11	Clamp	Aluminum	FOILS
G12C12	Clamp	Aluminum	FOILS
G13S01K	Bolt	Steel	FOILS - Box 06
G13S01L	Bolt	Steel	FOILS - Box 06
G13S02O	Bolt	Steel	FOILS - Box 06
G14S01O	Bolt	Steel	FOILS - Box 06
G15S01E	Bolt	Steel	FOILS - Box 06
G20S01F	Bolt	Steel	FOILS - Box 06
G21S01I	Bolt	Steel	FOILS - Box 06
H01C01	Clamp	Aluminum	FOILS
H01C05	Clamp	Aluminum	FOILS
H01C08	Clamp	Aluminum	FOILS
H01C09	Clamp	Aluminum	FOILS
H01C10	Clamp	Aluminum	FOILS
H01C12	Clamp	Aluminum	FOILS

SURFACE	COMPONENT	MATERIAL	LOCATION AND COMMENTS
H01H02	Shim	Aluminum	FOILS - Box 05
H01S03C	Bolt	Steel	FOILS - Box 05
H03C01	Clamp	Aluminum	Zolensky
H03C02	Clamp	Aluminum	FOILS
H03C04	Clamp	Aluminum	FOILS
H03C06	Clamp	Aluminum	FOILS
H03C08	Clamp	Aluminum	FOILS
H03C09	Clamp	Aluminum	FOILS
H03E00A	Experiment Tray	Lexan Sheet	FOILS, Module B
H03E00B	Experiment Tray	Lexan Sheet	FOILS, Module B
H03F01	Frame	Al Z-Frame	FOILS, Frame Of Detector Stack
H03F02	Frame	Al Z-Frame	FOILS, Frame Of Detector Stack
H03R01	Reflector		FOILS - Box 01
H05C02	Clamp	Aluminum	FOILS
H05C03	Clamp	Aluminum	FOILS
H05C06	Clamp	Aluminum	FOILS
H05C11	Clamp	Aluminum	FOILS
H05C12	Clamp	Aluminum	FOILS
H05S02B	Bolt	Steel	FOILS - Box 02
H05S06C	Bolt	Steel	FOILS - Box 02
H06C01	Clamp	Aluminum	Zolensky
H06C02	Clamp	Aluminum	FOILS
H06C03	Clamp	Aluminum	FOILS
H06C08	Clamp	Aluminum	FOILS
H06C10	Clamp	Aluminum	FOILS
H06C12	Clamp	Aluminum	FOILS
H06F01	Frame	Al Frame	FOILS, Frame On Experiment Tray
H06F03	Frame	Al Frame	FOILS, Frame On Experiment Tray
H06S02C	Bolt	Steel	FOILS - Box 02
H06S04A	Bolt	Steel	FOILS - Box 02
H07C01	Clamp	Aluminum	FOILS
H07C04	Clamp	Aluminum	FOILS
H07C05	Clamp	Aluminum	FOILS
H07S11A	Bolt	Steel	FOILS - Box 01
H09C01	Clamp	Aluminum	Zolensky
H09C02	Clamp	Aluminum	FOILS
H09C07	Clamp	Aluminum	FOILS
H09C09	Clamp	Aluminum	FOILS
H09F03	Frame	Al Frame	FOILS, Frame On Experiment Tray
H09R01	Reflector		FOILS - Box 02
H09S02B	Bolt	Steel	FOILS - Box 02
H11C01	Clamp	Aluminum	FOILS
H11C02	Clamp	Aluminum	FOILS
H11C03	Clamp	Aluminum	FOILS
H11C05	Clamp	Aluminum	FOILS
H11C06	Clamp	Aluminum	FOILS
H11C12	Clamp	Aluminum	FOILS
H11H12	Shim	Aluminum	FOILS - Box 02, Shim Under Clamp 12
H11S01C	Bolt	Steel	FOILS - Box 01

SURFACE	COMPONENT	MATERIAL	LOCATION AND COMMENTS
H11S02B	Bolt	Steel	FOILS - Box 01
H12C02	Clamp	Aluminum	Zolensky
H12C04	Clamp	Aluminum	FOILS
H12C09	Clamp	Aluminum	FOILS
H12C10	Clamp	Aluminum	FOILS
H12C11	Clamp	Aluminum	FOILS
H12C12	Clamp	Aluminum	FOILS
H12E00A	Experiment Tray	Lexan Sheet	FOILS, Module G
H12E02	Experiment Tray	Multi-layered Blanket	FOILS, Module E
H12E03	Experiment Tray	Multi-layered Blanket	FOILS, Module G
H12E05	Experiment Tray	Multi-layered Blanket	FOILS, Module F
H15S01J	Bolt	Steel	FOILS - Box 06

4.B.6 Additional Teflon Thermal Blanket Samples

In addition to the one-third sections of each A0178 Teflon blanket curated by the M&D SIG at the Johnson Space Center, the remaining two thirds of each of these blankets is being maintained in Europe by ESTEC. Individuals wishing information concerning the possible analysis of portions of these blankets should contact Prof. J.A.M. McDonnell, and send a copy of all communications to Dr. K.-P. Wenzel (see addresses below).

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4.B.7 Availability Of Images Cited In This Document

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SECTION 5

RECOMMENDATIONS

5.A RECOMMENDATIONS

Our experience with the documentation of LDEF places us in an excellent position to make recommendations regarding future meteoroid and space-debris characterizations from the analysis of surfaces exposed in space. Examination of LDEF has reinforced the view, largely based on our experience with the Solar Maximum Satellite, that every surface exposed in low-Earth orbit will contain important information related to the general collisional environment, and certainly related to its own dynamic response and behavior during hypervelocity impacts. Inasmuch as the entire dynamic range of particulates in low-Earth orbit may not be suitably simulated in the laboratory, each surface returned from space represents a unique opportunity. We recommend that documentation of impact features be repeated at reasonable intervals on future spacecraft exposed for long durations so that the changing debris environment in low-Earth orbit can be monitored; a period of five to ten years between such efforts would appear to be reasonable.

It is paramount to subject such surfaces to survey-type analysis such as that conducted on LDEF. The potential variety of impact features must be assessed, documented, and understood. Such surveys will provide the context for detailed examinations by specialized interests which are generally performed on a limited number of carefully selected samples. The surveys render the detailed analyses purposeful and efficient, and also constitute the first step in the proper preservation and curation of valuable specimens.

We were very satisfied with the specific procedures developed to permit documentation of the impact record of LDEF; we suggest that these procedures be reviewed by investigators proposing to survey space hardware in the future. We note that, despite our best efforts at scheduling this work, the time available for the completion of the LDEF surveying was only barely adequate for the purpose, and recommend that this factor be taken into careful account in any future survey operations.

In the following paragraphs we make specific suggestions to permit the full realization of the opportunities offered by LDEF:

As the title of this document explicitly states, this is only a preliminary report regarding the characterization of impact features on LDEF. We are proceeding with the reduction of the stereo images collected for each documented feature, with the intention of obtaining accurate feature dimensions. These data are critical to a satisfactory understanding of the meteoroid and debris environment and the survivability of space hardware; however, the meteoroid and debris environment may be understood in detail only if compositional (including isotopic) analysis of a statistically representative population of LDEF impacts is performed. Experience gained from examined hardware returned from the Solar Maximum spacecraft points out the critical requirement for such analyses in the discrimination of natural meteoroids from space debris [Reference 3]. In particular, LDEF surfaces which exposed identical materials in most or all spatial directions should be utilized for these compositional analyses. These materials include the experiment-tray clamps, Teflon thermal blankets, and the frame of the LDEF itself. A comprehensive sampling of these critical materials has been obtained by the M&D SIG, and is now available for analysis by qualified investigators. We encourage the LDEF M&D SIG to follow-up on obtaining additional critical samples promised by various Principal Investigators.

To increase the survivability of space hardware to impact-related degradation and damage, the understanding of the morphology of impact features must be improved. The Teflon thermal blankets must be analyzed to determine the causes of ring formation and excessive delamination of layers, which degrade the thermal control capabilities of the blankets. Their performance as meteorite-bumpers should also be evaluated. In assessing impact-caused degradation of thermal surfaces, the delamination of thermal-control paints must also be examined. Finally, the fracture, delamination, and optical degradation of solar-cell cover glasses and sensor mirrors must be understood, including the effects caused by impacts into the interior walls and baffles of sensor telescopes, with resulting ejecta onto the sensor optics. This work would best be performed in conjunction with the LDEF Materials Principal Investigators and the Materials SIG.

Near-term design decisions for large-scale space structures, such as Space Station *Freedom* and the Strategic Defense System, will benefit from LDEF results only if the latter appear in a timely fashion. It is recommended and encouraged that all meteoroid and debris Principal Investigators and Special Investigation Group participants respond and assist by providing preliminary data and results for incorporation into an up-to-date database, largely formatted along engineering needs. Specifically, data on the directionality of natural and man-made impactors, and of the damage caused to a wide variety of spacecraft materials are needed, however preliminary.

We also recommend that the population of small impactors be characterized through a survey of the smallest size fraction of impact features on LDEF surfaces. Some of this work is already being performed by various LDEF Principal Investigators, but the M&D SIG possess suitable surfaces which faced in more LDEF-pointing directions than any one individual investigator. M&D SIG surveying operations could thus augment the data to be provided by the LDEF Principal Investigators.

To permit analytical results to be available for consideration by designers of Space Station *Freedom* and the Strategic Defense System, we recommend that the work described above be given immediate support.

In addition, we recommend that the listing of curated M&D SIG materials provided within this document be updated and furnished by the JSC Curatorial Facility in the form of a periodic newsletter. This publication would be completely analogous to the Cosmic Dust Newsletter already published at irregular intervals by the Curatorial Facility.

As advertised, LDEF should provide a unique view of the meteoroid complex. We recommend that compositional, isotopic, and mineralogic analyses be performed upon impactor residues contained within LDEF impact features, particularly those which faced in directions not frequented by space debris.

We recommend that this publication be superseded, in approximately two years, by a document that will contain the collected results of continued analyses of LDEF impact features supported by the M&D SIG, together with a summary of parallel investigations by LDEF Principal Investigators. The Curatorial Facility at JSC has developed an LDEF impact-feature database which should be used by all meteoroid and debris investigators. This database should provide a unifying framework for all LDEF meteoroid and debris data, and serve as the foundation for the subsequent M&D SIG publication.

In conclusion, we emphasize once again that the opportunities afforded by LDEF are unique. The characterization and documentation of impact features described in this publication are but a first step in realizing this potential, and in providing guidelines for promising, detailed investigations. Without timely and adequate support of the latter studies, improved understanding of interplanetary dust, the nature of orbital debris, and of their combined collisional threat to spacecraft will not be possible.

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SECTION 6

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